

**ETHNOGRAPHIC STUDIES OF SCHOOL SCIENCE AND SCIENCE
COMMUNITIES**

A Dissertation

by

MEHMET CIHAD AYAR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2012

Major Subject: Curriculum and Instruction

Ethnographic Studies of School Science and Science Communities

Copyright 2012 Mehmet Cihad Ayar

**ETHNOGRAPHIC STUDIES OF SCHOOL SCIENCE AND SCIENCE
COMMUNITIES**

A Dissertation

by

MEHMET CIHAD AYAR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Co-Chairs of Committee, Cathleen C. Loving

Bugrahan Yalvac

Committee Members, Wenda K. Bauchspies

Jeffrey Liew

Scott Slough

Head of Department, Yeping Li

May 2012

Major Subject: Curriculum and Instruction

ABSTRACT

Ethnographic Studies of School Science and Science Communities.

(May 2012)

Mehmet Cihad Ayar, B.S. /M.S. Bogazici University;

M.S., Marmara University

Co-Chairs of Advisory Committee,

Dr. Cathleen C. Loving

Dr. Bugrahan Yalvac

In this dissertation I used the anthropological and sociocultural perspectives to examine the culture of school science and science communities. I conducted three independent studies. The first study is a meta-ethnography of three well-known case studies published in the literature. I analyzed these studies in order to identify the distinct characteristics of scientific communities and portray a picture of how science is practiced. The meta-ethnographic analysis reveals aspects of scientific practice that are insightful for the science educators and curriculum developers because these aspects are often neglected in school science even though they explain how science is done and accomplished in science communities.

In the second study, I conducted an ethnographic research to explore the distinct characteristics of a scientific-engineering community. How the community members worked in collaboration as they conducted their research, how they negotiated and mutually agreed upon as they interacted and communicated with one and another and

what they have learned through the process of these interactions were the units of the analyses. Findings reveal that the lead scientists' different working styles in the research center orchestrated learning and research. Ongoing communication and interdisciplinarity initiated collaborative partnerships with other communities and allowed the research groups to generate a shared repertoire to pursue the novelty in the process of knowledge generation. Mentorship was a catalyst for enculturation process, and it was on the trajectory of becoming an engineering university faculty.

In the third study, I observed a science classroom over a period of time to explore the socio-cultural aspects of learning. I examined the social practices and the participants' interactions that establish and maintain participation, community, and meaning. In my analysis I investigated the extent to which students' participation and interaction formed a community of practice and fostered learning science.

The three studies highlight the distinct characteristics of school science communities and science communities that are of importance for the efforts to better design learning environments. Translating the everyday activities of scientists and engineering researchers into school science communities can help enhance students' science learning experiences and cultivate a more informed understanding of science and engineering.

DEDICATION

I would like to dedicate this dissertation to my parents, Ali and Halime Hacer and my wife, Aylin for their support, love, and affection over the last five years and those who participated in this research.

ACKNOWLEDGEMENTS

This doctoral journey began six years ago. There are many people who I would like to express my gratitude for helping me start and complete this adventure: my parents and my wife who supported me to come to the US and pursue a doctoral degree in my professional life. I am grateful to my mother, Halime Hacer and my father, Ali for their encouragement and to my wife, Aylin Kaya Ayar, for her love and patience.

I would like to thank my study participants. This dissertation would not be possible without their participation and invaluable support. Their emic perspectives met with my etic perspectives to portray their learning and practices in their communities.

For financial aid to help with completing my doctorate, I thank the Department of Teaching, Learning and Culture, National Science Foundation funded Live Energy project, and the Office of Graduate Studies' Dissertation Fellowship at Texas A&M University. I feel honored to benefit from the scholarships and fellowship celebrating their contributions to my education.

I want to thank my co-chair Dr. Loving. Dr. Loving opened a door for me to start my doctoral study at Texas A&M University in 2007. I am glad that I have taken many science education courses within historical, philosophical, social and socio-cultural contexts. These courses helped me develop my understanding of science and go beyond. With her invaluable support and guidance, I learned new things from her during my dissertation journey.

I feel fortunate to have Dr. Yalvac as co-chair in my dissertation committee. Since the beginning of my doctoral adventure, he has supported and encouraged me to be a good science educator and researcher. He introduced me to the world of qualitative research early in the dissertation study and fostered my self-confidence. He provided me with the opportunity to meet my committee member, Dr. Bauchspies. Dr. Yalvac and Dr. Bauchspies motivated me to shift my interest towards sociological and anthropological viewpoints of science and to conduct ethnography in the dissertation. Their guidance helped me develop my own practice as a researcher and educator. I am very grateful that Dr. Yalvac and Dr. Bauchspies guided me to complete this dissertation.

I would like to thank my committee members, Dr. Liew, and Dr. Slough for their guidance and support throughout the course of this research. I am glad that they challenged me with their constructive feedback to enhance the quality of my research.

I have come to understand that the writing of this dissertation is not a solitary pursuit. Instead, it consists of collectivity and collaboration that allowed me to finish this work. I would like to thank you all.

NOMENCLATURE

KEK	Ko-Enerugie butsurigaku Kenkyusho
NRC	National Research Council
PDB	Protein Data Bank
SLAC	Stanford Linear Accelerator Center
STEM	Science, Technology, Engineering, and Mathematics

TABLE OF CONTENTS

	Page
ABSTRACT	iii
DEDICATION.....	v
ACKNOWLEDGEMENTS	vi
NOMENCLATURE	viii
TABLE OF CONTENTS.....	ix
LIST OF FIGURES	xi
LIST OF TABLES.....	xii
 CHAPTER	
I INTRODUCTION.....	1
Progression of the Research	6
Significance of the Research	7
 II INTERPRETIVE STUDIES OF SCIENCE: A META-ETHNOGRAPHY	10
Overview	10
Introduction	11
Theoretical Perspectives.....	12
Methods	17
Results.....	21
Discussion	39
Concluding Remarks	41
 III PORTRAYING THE DISTINCT CHARACTERISTICS OF A SCIENTIFIC-ENGINEERING COMMUNITY	46
Overview	46
Introduction	47
Theoretical Framework	48
Methods.....	55
Findings.....	61
Discussion	85

CHAPTER	Page
Implications for STEM Learning Environment Design	90
Concluding Remarks	95
IV EXPLORING SOCIAL DYNAMICS IN SCHOOL SCIENCE CONTEXT: AN ETHNOGRAPHIC STUDY	96
Overview	96
Introduction	97
Theoretical Framework	100
Methods	107
Vignette Introduction	112
Findings	120
Discussion	130
Concluding Remarks	141
V SUMMARY	145
REFERENCES	151
APPENDIX A	177
APPENDIX B	178
VITA	179

LIST OF FIGURES

FIGURE		Page
1	Connections among Individuals in the Research Groups	63
2	Closing Motion of Adenylate Kinase	75
3	Opening/Closing Motion of Type II Restriction Endonuclease.....	75

LIST OF TABLES

TABLE		Page
1	Steps in Meta-Ethnography	20
2	Key Descriptors of Scientific Practice	28

CHAPTER I

INTRODUCTION

In the twenty-first century, as a response to scientific, technological and economic competition, new strategies are being proposed and taken to review, revise, and reestablish our educational systems. Education standards, reform documents, and policies emphasize scientific and technological literacy (American Association for the Advancement of Science, 1993; National Research Council [NRC], 2003). The new generation is expected to develop and practice critical thinking, effective communication, adaptive expertise, group work, problem solving, and computational thinking skills (Bybee, 2010; NRC, 2011). Along with core content, these skills are viewed as essential for the new generation to be able to contribute to the scientific and economic growth and compete in the global economy (NRC, 2010).

As we are living in a global village, we need to provide every student with the opportunity to learn within and across communities of practice, develop expertise, personal identities, and researcher roles, and gain competence to think globally and act locally. Three studies in this dissertation contribute to this need by exploring and examining the distinct characteristics of science/engineering and school science communities to better design learning environments.

This dissertation follows the style of *Journal of the Learning Sciences*.

The three studies address the daily activities of two groups of people: (a) scientists and engineers, and (b) middle school students. Their community interactions and communications are the foci of discussion as they are engaged with a shared practice. Exploring the social organizations of science/engineering and school science communities helps inform science education researchers, learning scientists, and curriculum policy makers to more effectively design innovative learning practices within and across classroom communities.

Research on how individuals learn points out that learning is now understood to exist within the contextual practices that individuals perform in communities (Barab & Duffy, 2000; Bransford, Brown, & Cocking, 2000; Collins, 2006; Wenger, 1998, 2010). Sociocultural studies of learning support the idea that learning occurs through collaboration and social interaction as individuals legitimately participate in cultural activities (Bielaczyc & Collins, 1999; Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Sawyer, 2006; Wenger, 1998).

Learning occurs as individuals adapt a set of norms, beliefs, and knowledge that enable them to become more central members of the community; it transforms their identities on the trajectory of learning as they develop expertise (Lave & Wenger, 1991; Nasir & Cooks, 2009; Wenger, 1998). From these perspectives, learning is not only simply a mental process occurring within the head of a learner, but a social becoming in a community, all of which characterize communities of practice as social learning systems (Wenger, McDermott, & Snyder, 2002; Wenger, 2010).

The concept of a social learning system provides us a broader conceptual framework for understanding how individuals learn in social contexts such as science classrooms and research laboratories (Lave & Wenger, 1991; Wenger, 1998, 2010). On one hand, science classrooms are sites where students and the teacher form a social group and develop social relationships to reconstruct their understanding. Students and the teacher are expected to transform roles and identities, establish cultural norms to sustain their participation in activities in a community, generate and use material and discourse resources to perform classroom practice, and gain competence to reproduce ready-made scientific knowledge (Archer et al., 2010; Cornelius & Herrenkohl, 2004; Lave & Wenger, 1991; Olitsky, Flohr, Gardner, & Billups, 2010; Shepardson & Britsch, 2006; Smithenry & Gallagher-Bolos, 2010; Wenger, 1998). On the other hand, research laboratories are more complex learning systems where the social, cultural, historical, cognitive, and affective aspects of scientific and engineering works are converged (Knorr-Cetina, 1999; Nersessian, 2006; Osbeck, Nersessian, Malone, & Newstetter, 2011; Sismondo, 2010; Vinck, 2003, 2010).

The social organization of a research laboratory consists of scientists, engineers, technicians, administrative personnel, and others (e.g., students and practitioners) and can be based upon gender-based and power-based hierarchies among the lab members (Buxton, 2001; Traweek, 1988; Vinck, 2010). The members participate in normative, ongoing activities of the laboratory. Newcomers adapt the cultural norms to become a member of the laboratory. Scientists and engineers generate temporally emergent goals to perpetuate their investigations as the material culture of the laboratory evolves. As

new technologies and methodologies emerge, the culture of the research laboratory renews. At the same time, scientists and engineers develop multi-memberships across other communities, which in turn, initiate dynamic and collaborative partnerships to pursue the novelty and sustain the credibility of their work. All of these characterize science and engineering communities as sociocultural and cognitive systems that construct the social world and the material world to perform their work.

Usually, anthropological approaches have been the primary mode of inquiry for exploring and examining the distinct features of school science and professional science and/or engineering communities. As an anthropological approach, ethnography relates cultural, collective activities to a particular group of people (in this case, science learners and engineering researchers). It draws attention to the norms, beliefs, knowledge, and practice that individuals share in their social system. It enables capturing the development of role and identities, appropriate technologies, enculturation process, and contextual practices in the science classroom and the research center. It seeks to uncover the daily activities, material and discourse resources, and participation patterns. It provides a lens for describing and interpreting the social organization of the natural settings. Thus, ethnography as a mode of inquiry allows us to convey, socially, construction of cultural meanings of both school science and professional science communities to the interested parties as etic and emic perspectives are juxtaposed.

Ethnographic studies in science and science education are a means for further understanding the cultural portrait of both professional science and school science communities. First, the origins of this study arose from ethnographic studies of science

that highlights the mutual relationship between the social world and the material world in the construction of scientific facts and scientific community (Latour & Woolgar, 1986; Trawick, 1988). In this view, examining the ethnographies of science is a method for understanding the commonalities and differences of scientific practice that shed light on the common characteristics of scientific communities.

Second, studying science and engineering communities has become prominent in the learning sciences and science education communities to design learning environments (Ayar & Yalvac, 2010; Roth, 1998; Yerrick & Roth, 2005). Investigating the distinct features of science and engineering research laboratories has helped us understand the culture that facilitates learning and research, and that delineate socio-cultural and cognitive practices in the knowledge generation process (Bauchspies, Croissant, & Restivo, 2006; Nersessian, 2005, 2006). To explore the social organization of scientific and engineering work as well as communication and interdisciplinarity in research laboratories is a way to translate a more realistic representation of scientific and engineering research practices into school science context in order to go beyond learning from following instructions through which students performed structured laboratory activities.

Third, ethnographic studies of school science provide a lens for identifying the characteristics of classroom communities in regard to identities, competence, expertise, practice, and participation (Aguilar, 2009; Aschbacher et al., 2010; Enyedy & Goldberg, 2004; Olitsky, 2007; Olitsky et al., 2010; Shanahan & Nieswandt, 2011; Smithenry & Gallagher-Bolos, 2010). Studying the everyday activities of students and the teacher and

examining the social structure of a science classroom can help identify dynamics that play a significant role in developing and sustaining a community of practice in a school science context.

This dissertation examine the past science communities, a current scientific-engineering community, and a school science classroom community to better design learning environment. Therefore, the purpose of this research was three-fold: (1) to analyze three exemplary ethnographies of science, to present the commonalities and differences among them, to build a portrait of how science is accomplished, and to synthesize the three studies' themes for use in understanding scientific practice in the science classroom; (2) to explore the culture of a scientific-engineering community and the distinct characteristics of the community members' interaction, and to study how learning and research is sustained in a community; (3) to study the social organization of a school science classroom and identify barriers to and opportunities for the emergence of community of practice in a school science context.

Progression of the Research

Three related studies were conducted to understand ethnographies of school science and science/engineering communities more. The first study examines three interpretive studies of science through meta-ethnographic analysis and identifies converging themes that represent the practice of science in the process of knowledge construction and reproduction of communities. The second study delineates the culture of the scientific-engineering community and explores the interactions and communications that sustain learning and research in the field of computational biology.

The last study investigates a science classroom within the context of communities of practice and discusses barriers and opportunities to a community of practice in a school science context.

Research Questions

1. What are the descriptions of scientific practice portrayed by ethnographic studies of science? What is the role of the laboratory?
2. What are the distinct characteristics of a scientific-engineering community?
 - a. How do the community members (the university faculty and the graduate students) sustain learning and research in their community?
 - b. How do the community members operationalize their scientific and engineering practices within their community?
3. What are the distinct characteristics of a science classroom community?
 - a. What is the nature of the ‘participant structures’ (barriers and opportunities) emerged in the cultural events?
 - b. What dimensions of the communities of practice emerge?
 - c. What is the nature of participants’ science practices?

Significance of the Research

Studies that investigate science communities have contributed to our understanding of various aspects of scientific practice and the process of knowledge construction. Different methodologies have been used to represent science and its enterprise and describe the nature of scientific work. The products of research have been

discussed, utilized, and transformed in different disciplines. In educational settings (e.g., science classrooms), the science education community has been integrating important aspects of scientific practice to familiarize individuals with a more realistic representation of doing science and design authentic learning environments where individuals are provided with authentic research experiences (Ayar & Yalvac, 2010). More importantly, their efforts to do so are aimed to narrow the gap between school science and science communities because the everyday activities in school science communities do not resemble those in science communities. Scientists endeavor to generate new knowledge in their communities, whereas students acquire and confirm the defined knowledge to perform their classroom activities. In other words, they are given the opportunity to perform the safe version of real science activities. These activities are occasionally open-ended, structured, and lacking uncertainty.

This gap has emerged from the misrepresentations of scientific work, or the way scientists perform their investigations to understand natural phenomena, and the lack of authenticity (associated with the social, cultural, material, cognitive, and other dimensions of science communities) in school science context. Accordingly, there is a need to explore past and present scientific communities and build a connection with school science communities in order to contribute to the efforts in narrowing the gap.

For a thorough understanding of scientific communities, being informed about the dimensions of past scientific communities provides a lens to reconceptualize the emerging perspectives of scientific practice. Since the material world and the social world change and advance, the everyday activities of scientists and engineers evolve

over time. To better understand the current scientific and engineering communities, individuals should be informed about complex learning and research systems in scientific-engineering communities. To accomplish the translations of scientific-engineering communities' dimensions into school context, individuals should be informed about the social structure of classroom communities and dynamics that impact the sustainability of learning and communication to establish a community of practice.

The research that juxtaposes the aspects of past and present scientific-engineering communities with those of school science communities is crucial to design learning environments in general, and to support the efforts to create knowledge-building classroom communities in particular. More specifically, this research is a means to establish better strategies for translating the methodologies, technologies, and perspectives on learning and research emerged in science and engineering communities into school science context.

CHAPTER II
INTERPRETIVE STUDIES OF SCIENCE:
A META-ETHNOGRAPHY

Overview

This study aims to examine the meaning of scientific practice in three case studies in order to present the commonalities and differences among the three ethnographic studies, to identify the distinct characteristics of scientific communities, and to portray a picture of how science is accomplished in order to translate them for use in understanding scientific practice in the science classroom. Using meta-ethnography I ask the research questions: “What are the concepts or themes commonly used to describe how science is practiced? And how is that description applied and interpreted? And what is the role of the laboratory?” The study has three sections: (1) overview of the three selected ethnographic studies, (2) key descriptors and translations used within the studies, and (3) synthesis and translation for a science education community. The meta-ethnographic analysis reveals aspects of scientific practice that may be useful for the science education community to consider from the material culture that shapes scientists’ activities, public credibility, and transforms the community to the discursive activities that are inherent in scientific communities and the construction of scientific knowledge. Additionally, the study highlights how the professional scientific laboratory is a system of literary inscription, the production of images, and reproduction of culture and what this means for the science laboratory in the classroom.

Introduction

It is largely accepted that science is a complex and multifaceted activity (Erickson, 2005). The most tangible aspect of science is that it is a social institution that includes a variety of people performing specific activities to better understand natural phenomena and to produce rational knowledge as well as to gain credits in communities of scientists (Latour & Woolgar, 1986; Vinck, 2010; Ziman, 2000).

Different fields of study examine science and its enterprise differently. On one hand, philosophers developed philosophical understandings of science in regard to the justification, methodology and content (Hoyningen-Huene, 2006; Kantorovich, 1988; Knorr-Cetina, 2001; Sismondo, 2010), whereas historians drew our attention to scientific content and theories, and the development of historical artifacts (e.g., instruments) and ideas (Knorr-Cetina, 1995; Vinck, 2010). On the other hand, sociologists of science have been interested in exploring the whole process of knowledge generation, the social structure of science, and the norms of scientific practice (Duschl, 2008; Knorr-Cetina, 1981, 1995; Sismondo, 2010; Vinck, 2010). History and philosophy of science enrich our understanding of science and the use of experiments in science while sociology of science highlight the role of laboratories as natural sites for knowledge generation of science (Knorr-Cetina, 2001).

In this study; I draw on three exemplary ethnographic studies emphasizing sociology of science to ask “What are the descriptions of scientific practice portrayed by ethnographic studies of science? How is that description interpreted? What is the role of the Laboratory?” The three studies are: (1) “Laboratory Life: The Construction of

Scientific Facts” (Latour & Woolgar, 1986), (2) “Beamtimes and Lifetimes: The World of High Energy Physicists” (Traweek, 1988), and (3) “Art and Artifact in Laboratory Science” (Lynch, 1985). To answer these questions, I documented and analytically examined the concepts that the authors of these ethnographic studies used to represent and interpret the practice of science and knowledge generation process through meta-ethnography as a mode of inquiry (Doyle, 2003; Noblit & Hare, 1988).

The main purpose is to present the commonalities and differences among the three ethnographic studies, to identify the distinct characteristics of scientific communities, and to portray a more holistic picture of how science is accomplished in order to translate them for use in understanding scientific practice in the science classroom.

Theoretical Perspectives

Sociology of Science

The study of science as an object of study has expanded and grown in the later half of the 20th century. Now commonly called, the sociology of science, it offers a variety of perspectives such as the normative structure of science (Merton, 1973), the Strong Programme (Bloor, 1991) associated with the sociology of scientific knowledge, and Laboratory Studies (Knorr-Cetina, 1995; Restivo & Zenzen, 1982). The Mertonian understanding of science is grounded on the ethos of science and the norms guiding scientific practice (Sismondo, 2010). Merton describes the four norms: universalism, communism, disinterestedness, and organized skepticism so that the main idea behind his thinking of science is to provide “certified knowledge” (Merton, 1973, p. 270). His

understanding of science helps us conceptualize the social system of science (Kelly, Carlsen, & Cunningham, 1993). A pioneer of the Strong Programme, Bloor (1991) explains the development of scientific knowledge through four tenets—causality, impartiality, symmetry, and reflexivity. Bloor identifies how social interests and local cultural systems shape and guide scientific inquiry.

Methodologies of ethnography and ethnomethodology have followed the theoretical work of Merton and Bloor to understand scientific and technological practices and are called laboratory studies (Knorr-Cetina, 1995). These studies explore the norms and characteristics of scientific practice and explain the constructive nature of knowledge production (Knorr-Cetina, 2001). Through participant observations in research laboratories, these field studies have augmented our understanding of science as practice and culture (Pickering, 1992; Ziman, 2000).

Laboratory studies' researchers highlight the mutual relationship between the social world and the material world in the generation of scientific facts (Knorr-Cetina, 1981, 1999; Pickering, 1999). Their observations along with a constructivist approach delineate day-to-day practices of scientists, social accomplishments, and conceptual and practical culture of a research laboratory. These studies provide a cultural framework to describe how scientific facts or cultural entities are created technically and construed symbolically and politically (Knorr-Cetina, 2001).

The Rise of Laboratory Studies

Laboratory studies arose when sociologists, anthropologists, and ethnographers began to study science and technology in the early 1970s in order to directly observe scientists' everyday activities and identify the knowledge-generation process.

Researchers wanted to conceptualize the development of scientific statements from the practice of science (e.g., Knorr-Cetina, 1983; Latour & Woolgar, 1986; Traweek, 1988).

Some of these early ethnographies identified by Vinck (2010) include: the Belgian physicist and philosopher, George Thill, who studied the high-energy physics laboratory to describe the epistemic, organizational, and sociological dimensions of scientific practice in 1973. Gerard Lemaine and his colleagues analyzed a neurophysiology laboratory within the institutional and organizational contexts in 1977. In 1982, Terry Shinn examined physics, chemistry, and information technology laboratories.

In the early 1980s, three concurrent and independent studies of laboratories in the state of California emerged. The French philosopher Bruno Latour and the sociologist Steve Woolgar performed a field study of a biochemistry laboratory entitled: *Laboratory Life: The Construction of Scientific Facts*. At the same time, the German sociologist, Karin Knorr-Cetina studied a biochemical laboratory through a constructivist perspective. She wrote *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Knorr-Cetina, 1981). She extended her analyses and later wrote *Epistemic Cultures* (Knorr-Cetina, 1999). In 1985, Michael Lynch published his ethnomethodologic study involving neurosciences laboratory that addressed the social and practical accomplishments in situ of an order of knowledge. An American

anthropologist, Sharon Traweek (1988) used symbolic anthropology to study two high-energy physics communities. Her ethnography explored and compared the cultures of laboratories in Japan and the US. In later years, the idea of the laboratory study along with the use of ethnography stimulated other researchers to be interested in technological practices in engineering (Bucciarelli, 1994; Vinck, 2003) and nanoscience/technology (Fogelberg & Glimell, 2003).

There are also numerous studies of ethnographies of science published in journal articles. I briefly describe them to reveal that there are numerous studies investigating research laboratories within a sociocultural context and that tradition is alive in well in contemporary research. For instance, Buxton (2001) examined a molecular biology research laboratory to discover the day-to-day practices of the lab members, their roles and their relation with others, their interest, and the features of a scientific community. Buxton elicited the norms of behavior that guide scientific practice such as competence, work ethic, and passion. Newcomers were expected to adopt these norms to contribute to the work of lab. She noted a status hierarchy among the lab members in regard to space allocation due to their education level and their expertise. She concluded that the lab director's management style played a significant role in forming the social structure of the lab and establishing the work relations between the members.

Likewise, Feldman, Divoll and Rogan-Klyve (2009) investigated identity transformation, membership, and reconfiguration of research groups when individuals were engaged in empirical research. They found that individuals' identities were

transformed from novice researcher to proficient technician, to knowledge producer. Throughout this transition, individuals gained skills and beliefs to continue to do scientific investigations and become members of a scientific community. They noted that the research group leaders impacted the configuration and organization of their research groups and the social interactions among the group members.

Other studies conducted in research laboratories represented social, cultural, and material dimensions of scientific practice (Buxton, 2001; Feldman et al., 2009; Knorr-Cetina, 1981; Latour & Woolgar, 1986; Lynch, 1985; Nersessian, 2005; Traweek, 1988). Yet, some researchers have been interested in exploring cognitive accounts of knowledge-generation (Nersessian & Patton, 2009). Nersessian and her colleagues' studies highlight reasoning and representational practice in problem solving in biomedical engineering laboratories. They have contributed to our understanding of model-based reasoning, problem solving process, a set of repertoire (e.g., representation tools, forms of discourse, and activities) employed in creating and using knowledge. Moreover, they highlighted challenges researchers encountered, learning and development in the lab environment, and sense making and identity (Nersessian, 2005, 2006, 2009; Nersessian & Patton, 2009; Osbeck, Nersessian, Malone, & Newstetter, 2011).

As a result, laboratory studies have helped to reveal the social and cultural characteristics of science and technology as social constructions (Bauchspies, Croissant, & Restivo, 2006). They highlight the social events that scientists and engineers participate in within their community, the communications and negotiations that they

have with other members, and the daily interactions between human agents and non-human agents (Sismondo, 2010). They help us to conceptualize the organizational dimensions of the laboratory (Knorr-Cetina, 1995). The laboratory itself is a site for the manufacture of knowledge and a salient agency of scientific development (Knorr-Cetina, 1981). It is a site for persuasion and it is a system of fact construction (Latour & Woolgar, 1986). Laboratory is an evolving complex system that has epistemic, social, cultural, cognitive and historical dimensions. Thus, a practical conclusion is that the laboratories are strategic sites for researchers to study in order to understand scientific work and organization (Owen-Smith, 2001).

Methods

Background

The goals in this study are (a) to examine three ethnographic texts of science in order to explore and compare similarities and differences of each ethnographic text with regards to how science is done and practiced and (b) to synthesize these texts in such a way that it contributes to our knowledge and understanding of studying scientific practice in the classroom.

Meta-ethnography is a mode of inquiry that lays a foundation for the synthesis of qualitative studies. It is a means for critically examining multiple cases, comparing them to make cross-case conclusions, and relating them to one another in order to synthesize interpretations in ethnographic studies (Britten et al., 2002; Doyle, 2003; Noblit & Hare, 1988). Meta-ethnography researchers use these interpretations and explanations in the original studies to be treated as data and translate them across these studies to produce a

synthesis. Thus, meta-ethnography is interpretive rather than aggregative (Doyle, 2003; Noblit & Hare, 1988; Thorne, Jensen, Kearney, Noblit, & Sandelowski, 2004).

There are two known methodologies that resemble to meta-ethnography in terms of a synthesis of collection of studies: (1) meta-analysis and (2) literature review. Yet, these methodologies are different from each other. For example, while meta-ethnography is to construct and yield interpretations across studies through synthesis, meta-analysis aggregates findings for prediction and synthesizes the data for generalization. Literature review builds links between past and future studies to produce logical and deductive rationalizations for further research (Doyle, 2003).

Conducting Meta-Ethnography

To conduct this meta-ethnographic study, a seven-step process (Noblit & Hare, 1988) illustrated in Table 1 was employed. Some enhancement strategies that Doyle (2003) developed to boost the process of case selection, analysis, and synthesis were applied. I started with the first step, *getting started*, in which an intellectual interest was identified by asking, “How can an intellectual interest be informed by examining some ethnographic studies of science?” In Step 2, *deciding what is relevant to the initial interest*, I decided to focus on interpretive studies of science to understand and represent scientific practice. A maximum of four ethnographies was recommended to use for analysis in a meta-ethnographic study (Doyle, 1998, 2003; Noblit & Hare, 1988). For case selection, Noblit and Hare (1988) state that “what accounts are available” guides case selection (p.27). Additionally, I followed the criteria that expand Noblit and Hare’s condition for case selection. The criteria developed by Doyle (2003) aim to boost case

selection and include enhancement strategies that provide the potential audience with an intense focus of meta-ethnography. Therefore, I used the criteria that each study had to include multiple data sources, be of long in duration, and be complete. The criteria for book-length works were foundational to the field of science and technology studies that specifically explored laboratory science and scientific practice through ethnographic investigations. Regrettably I recognize that these criteria eliminated some excellent scholarship of the same time period simply because they were journal articles (Restivo & Zenzen, 1982; Star & Griesemer, 1989). The three published book ethnographies selected for the meta-ethnography of scientific practice (Latour & Woolgar, 1986; Lynch, 1985; Traweek, 1988) provided an extensive amount of data to sufficiently address the research questions. I will describe each of these studies in further detail in the next section when I present the results of the meta-ethnography.

Step 3 involved the meticulous reading of the selected ethnographic texts to identify the main concepts. In this step, through repetitive reading studies, I recorded the details of each study, not limited to the study setting, participants, and methods used, including concepts, explanations, and interpretations addressed by the authors of the ethnographic case studies. Throughout my reading of the texts, I made an initial decision about how these studies are linked to each other, which is called Step 4 (*determining how the studies are related*) (Noblit & Hare, 1988). This step generated list of potential descriptors summarized in Table 2. Determining descriptors was an enhancement strategy for case analysis (Doyle, 2003).

TABLE 1
Steps in Meta-Ethnography

<i>A Seven-Step Process</i>	
<hr/>	
1.	Getting started: The meta-ethnographer identifies an intellectual interest that qualitative research might inform.
2.	Deciding what is relevant to the initial interests. The meta-ethnographer decides what is relevant to initial interests, including what studies to include.
3.	Reading the studies. This is not a one-time event; as the synthesis develops, studies are read and reread to check the relevant metaphors and interpretations.
4.	Determining how the studies are related. Lists of key metaphors, phrases, ideas, and/or concepts and their relationships are made for each study and juxtaposed with those of other studies. This phase is complete when the initial assumption about the relationship between the studies can be made.
5.	Translation. Translating involves treating the accounts as analogies. An adequate translation maintains the central concepts of each account in their relationship to concepts in account while comparing them to the relevant concepts in other accounts.
6.	Synthesizing translations. Translations are the first level of a meta-ethnographic synthesis. The various translations can be compared with one another to determine if some concepts are able to encompass those of other accounts. If so, a second level of synthesis is possible: analyzing types of competing interpretations and translating them into each other.
7.	Expressing the synthesis. A meta-ethnography must be 'translated' into 'language' of the intended audience. This involves using the forms and concepts appropriate for that audience.

Note: Steps in meta-ethnography are retrieved from Meta-ethnography: Synthesizing qualitative studies. G.W. Noblit & R.D. Hare, 1988. Beverly Hills, CA: Sage.

In Step 5, Noblit and Hare (1988) propose *translating the studies into one another*, which implies comparing the concepts in one account with the concepts in others. In order to do this, I started to extract key descriptors from each study that identified the individual descriptive narratives of the each ethnography. I then translated the concepts of one author into the narrative of the others and vice versa, to understand the descriptors from various perspectives. In step 6, *synthesizing translations*, Noblit and Hare (1988) suggest juxtaposing concepts (e.g., descriptors) and translations of individual studies to develop a synthesis. I closely examined my three translations in order to write my final narrative. I followed the line of argument as a strategy in which to establish comprehensibility of the final synthesis (Noblit & Hare, 1988; Doyle, 2003). The final step is where the meta-ethnography is translated into the language of the intended audience, and is called: *expressing the synthesis*. My potential audience includes science education researchers, science teachers, and science education policy makers who want to understand the meaning of scientific practice in laboratories and beyond the classroom.

Results

In this section, I present the results of the meta-ethnographic analysis that begin with an overview of the studies included in the meta-ethnography. I identify key descriptors (e.g., concepts) from each case study and write descriptive narratives (e.g., translations), which would later allow me to make a synthesis of the studies. I illustrate the key descriptors that emerged from each study in Table 2. The last step is a synthetic statement of the three studies.

Overview of the Three Ethnographic Studies

As previously mentioned, ethnographies of science portray science as practice and culture (Pickering, 1992) and help us understand how the laboratory itself plays a pivotal role in the reconfiguration of entities from the natural and social world (Vinck, 2007). Thus my goal is to describe and summarize the three ethnographic texts of science in order to delineate the practice of science and the role of the research laboratories in knowledge generation.

The first ethnography discussed here was done by Bruno Latour and Steven Woolgar (1986) in the research laboratory at the Salk Institute. Their research focused on how facts are constructed in a laboratory and how a sociologist can account for this construction in *Laboratory Life*. Latour and Woolgar (1986, p. 40) studied “the work in which the daily activities of working scientists lead to the construction of scientific facts.” They specifically addressed questions such as, “What are scientists doing?,” “What are they talking about?,” and “How are they constructing scientific knowledge?” in order to portray the culture of scientists in a neuroendocrinology laboratory. Through their observations and interpretations Latour and Woolgar focused on how scientists integrated informal and formal writing in the construction of scientific knowledge and how creativity and imagination played a role in doing science and the production of knowledge.

Latour and Woolgar noted that scientists worked in competitive environments and challenged their peer’s work through questions related to the reliability of their scientific claims and the inscription devices used. Thus, they also looked at the role of

inscription devices in the production and consumption of facts. Scientists used persuasion to resolve others' challenging arguments and/or claims. Ultimately, they concluded that "the result of the construction of a fact is that it appears unconstructed by anyone; the result of the rhetorical persuasion in the agnostic field is that participants are convinced that they have not been convinced" (p.240). Latour and Woolgar concluded that the construction of facts is a long, gradual process of collective working to create order out of disorder.

The second ethnography was done by Michael Lynch (1985); it was an ethnomethodological study done in a neurosciences laboratory. Lynch was concerned with the production of technical work and technical talk. Lynch (1985, p.1) located his interest on the "social accomplishment of natural scientific order." To understand the account of technical talk and conduct in the lab environment, Lynch investigated several topics (e.g., temporalization and practical continuity) in the *Art and Artifact in Laboratory Science*. Lynch looked at the temporal features of work performance by addressing the actual order to the performance of "method" rather than the schematic order of a "methods" recipe (p.3).

Lynch noted that the laboratory's research is not uniform and is not a coherent process, but a variety of projects characterized the laboratory environment. Lynch investigated how scientists deal with troublesome artifacts in electromicrographs. He noted that the observability of the phenomena depended on complex instruments or techniques in the account of artifacts. Lynch accounted for "troubles" or "artifacts" as an identifying feature of local accomplishment of shop work. Thus, Lynch demonstrated

how artifacts were constituted and how scientists' distinction of facts from artifacts yielded the visibility of the laboratory work. Lynch focuses on how scientists come to resolve their disagreements in their conversations and how these disagreements are transformed into agreements.

The third ethnography addressed here was written by Sharon Traweek (1988) who conducted her fieldwork at three laboratories, primarily at the Stanford Linear Accelerator Center (SLAC), at Japan's KEK (Ko-Enerugie butsurigaku Kenkyusho) facility, and at Fermilab in Illinois. Traweek examined community life of the particle physicists, how their community emerged and evolved, how (male) physicists are made and reproduced, and how knowledge is constructed within the norms of the community of physicists, for example, the ability to distinguish "data" from "noise." Traweek conceived of laboratory sites as rich with disorder in *Beamtimes and Lifetimes*. She discovered, "most nonscientists think of labs as extremely clean, meticulously tidy places where people in immaculate white coats do their work with minute, precise movements, and that scientists work alone, in silence. High energy physics laboratories are not like that" (p.57).

Traweek pointed to hierarchy and male dominance among the physicists in the community in terms of the placement of graduate students, the evaluation of experiments, and access to equipment and facilities. She observed the role of the physicist network as a way for the novices to connect with the other particle physics community members. The network was essential for them to shape their careers in high energy physics. Traweek noted that "talk" was an essential notion in the particle physics

community. Physicists had to engage in discourse activities to negotiate time and lab resources as well as to distinguish data from noise. Through talk, physicists would evaluate the work of their peers and persuade their colleagues to support their work and sustain their membership in the community. Traweek drew attention to the role of the construction of research equipment or devices (e.g., machines or detectors) in cultivating successful physicists as well as in the process of knowledge generation. Traweek concludes that without these devices the particle physics community would not exist and evolve.

Key Descriptors

My reading of the three studies resulted in the key descriptors that are summarized in Table 2, and that will allow me to make translations and synthesis of the three works (Doyle, 2003). In this section, the key descriptors of the three case studies: construction, agonistic, materialization/reification, credibility, circumstances, noise, temporalization, projects, artifacts, agreements, modifications of objects, social organization, reproduction of physicists, masculine physics, and time, will be presented and translated.

Latour and Woolgar (1986) used six key descriptors to interpret how science is practiced. These descriptors are *construction*, *agnostic*, *materialization/reification*, *credibility*, *circumstances*, and *noise*. The slow, practical work of the laboratory is the construction of a fact through transforming a statement into an object or a fact into an artifact. In other words, the process of fact construction is characterized by stabilization of a statement where all references are included to persuade statements or claims. In the

“agnostic field,” (p.237) many characteristics of social conflict (e.g., disputes, forces, and alliance) and epistemological explanations of phenomena (e.g., proof, fact, and validity) are operationalized by scientists through the microprocesses of negotiation, which take place regularly in the context of the laboratory. That is, scientists perform operations on statements such as adding, withdrawing modalities, and proposing new combinations. Their operations result in a demodalized statement that is considered to be a fact. A fact can take the shape of an object or equipment (e.g., artifact) a few years later. For example, inscription devices can be derived from “the reification of theories and practices” or “a well-established body-knowledge” (p.68). Thus, “one cannot take for granted the difference between ‘material’ equipment and ‘intellectual’ components of laboratory activity” (p.238).

Materialization or reification refers to the process of material considerations as a component of the thought process in science. “Once a statement stabilizes in the agnostic field, it is reified and becomes part of the tacit skills or material equipment of another laboratory” (p.238). Incorporation of an intellectual component of laboratory activity into equipment allows scientists to obtain new, better inscription devices producing inscriptions and statements. This process provides them with the opportunity to gain a credit to do science and to reinvest credibility to make a move in scientific field via “cycles of credit” (p.201). Fact constructors deny that credit as reward is their motivation. Credit as reward cannot reflect the main purpose of their practicing science. In that regard, a working scientist does not ask, “Did I repay my debt in the form of

recognition because of the good paper he wrote?,” but asks “Is he reliable enough to be believed? Can I trust him/his claim? Is he going to provide me with hard facts?”(p.202).

The practice of science and its products are “entirely fabricated out of circumstance” (p.239). Eliminating circumstances from statements determines the construction of a fact. That is, when scientists performed operations on statements to be transformed into a fact, reality was distinguished from local circumstances. It is then concluded that “if reality is the consequence rather than the cause of this construction, this means that a scientist’s activity is directed, not toward “reality,” but toward these operations on statements” in the agnostic field (p.237). Investors of credibility consider their works as to whether they can convince their colleagues that data are different from the background noise produced in the laboratory. When a statement is transformed into a fact as a result of persuasion, efficacy of facts is evaluated and examined within the network or by “a set of positions” of scientific practice (p.107). Otherwise, the data would not be warranted as reliable.

TABLE 2
Key Descriptors of Scientific Practice

<i>Latour & Woolgar (1986)</i>	<i>Lynch (1985)</i>	<i>Traweek (1988)</i>
<u>Construction</u> Transforming a statement into an object. Stabilization of a statement.	<u>Temporalization</u> The production of extended courses of inquiry in lab work through the serial ordering of tasks in the immediacy of an organizational setting.	<u>Construction</u> Building and re-building machines (e.g., detectors).
<u>Agonistic</u> Many characteristics of social conflict and epistemological explanations of phenomena operationalized by scientists through the microprocesses of negotiation.	<u>Projects</u> Sequential units of interest in the production of lab inquiries. Sequentially arranged steps or “tasks.”	<u>Social organization</u> How a research group or the experimental physics community structures itself to continue lab work.
<u>Materialization/reification</u> The process of material considerations as a component of the thought process.	<u>Artifacts</u> Results of procedural excesses and inefficiencies. Emerge as “troubles.”	<u>Reproduction of physicists</u> Community evolves by transforming novices into physicists; from one stage to the next is dependent upon relationships within networks.
<u>Credibility</u> Gaining a credit allows scientists to make reinvestment of credibility to do science and make a move in the field.	<u>Agreements</u> Local occurrences the substantial part of the way laboratory works are performed. Achieved as a matter of assertion.	<u>Masculine physics</u> Physics as men’s expertise and competence.
<u>Circumstances</u> Eliminating circumstances from accounts determines the construction of a fact.	<u>Modifications of objects</u> Produced in the course of disagreement sequences.	<u>Time</u> The relation between “beamtime” and “lifetime”
<u>Noise</u> Data is different from the background noise produced in the laboratory.		<u>Noise</u> Beamtimes and lifetimes converge in detector which data is separated from noise and signals from nature are received.

Lynch (1985) addressed a variety of descriptors to delineate aspects of *in situ* scientific work, such as *temporalization*, *projects*, *artifacts*, *agreements*, and *modifications of objects*. Temporalization refers to “the production of extended courses of inquiry in lab work through the serial ordering of tasks in the immediacy of an organizational setting” (p.53). Lynch construes temporalization of practices as ongoing and developing achievements rather than as finished sequential products of projects of shop work. Projects are treated as sequential units of interest in the production of lab inquiries and essential features of lab shop work. A project encompasses sequentially arranged steps or “tasks.” These are “irreducible procedural elements of projects,” but “transferable across different projects” (p.66). Project as an analytic unit in the temporalization of the lab work is a contingent phenomenon shaped by the adequate performance of technical work in local circumstances. In other words, projects are bounded by scientists’ technical works, which have both definite beginning and concluding phases. This makes projects temporal phenomena in the social organization of lab work.

Artifacts are part of ongoing projects. They are the results of procedural excesses (for example, “intrusions” and “distortions” that appear in the natural phenomena) as well as the results of procedural inefficacies (for example, superstitions and the fallibility of procedures). The observability of artifacts depends on experimental procedure or instrument, for instance, electron microscopic photography, which makes invisible natural entities visible. Artifacts are not collected and analyzed, but emerge as “troubles” in the lab work. Artifacts are not certain “things,” but are possibilities related to absences

in an observation rather than definite constructive presences, for instance, spots or blurs in a photograph (p.86). When artifacts are identified, they are not considered as the accomplishments of a local inquiry. Instead, they are found as “mistakes,” “errors,” “unfortunate developments,” “problems,” “hassles,” “misleading appearances ”or“ equivocal interpretations” (p.88).

Lab members discuss the visibility of artifacts featured as indeterminate through assessments and agreements, and decide whether the material, for instance, micrographic montage can be used as data. Therefore, agreements are local occurrences in conversation where laboratory members make arguments over emerging problems, make plans to deal with it, and negotiate the reliability of the data for practical purposes of the local inquiry. That is to say, agreement among lab members is the substantial part of the way laboratory works are performed. Lynch states that agreement is achieved as a matter of assertion, but not through relating one utterance to another regardless of whether or not parties are telling “the truth” to one another or agree in their underlying attitudes or personal commitments (p.189). Modifications in scientific accounts of objects are produced in the course of disagreement sequences. This process is eased through “achieved agreement” (p.187) in a way that supports assertions and reassertions other than that reformulates those in scientific shoptalk.

The main descriptors in Traweek’s (1988) study are; *construction, social organization, reproduction of physicists, masculine physics, noise, and time*. By construction Traweek refers to building and re-building machines (e.g., detectors), which are at the heart of the particle physics community’s contextual activities, and are

locations where “physicists and nature” as well as “knowledge and passion” (p. 17) converge. A detector is constructed to sensitively identify and measure undesired disturbances (“noise,” p.50), collect data promptly, distinguish noise, and effectively analyze the data. Inventing detectors is a practice of physicists to discover nature because detectors determine strategies for scientific research and research questions. Building a new detector that effectively detects and records the traces of particles brings to physicists “great honor” and “influence” (p.49) in the community. A detector that perfectly functions at all times is shared with scientists in other fields and then it becomes obsolete for high energy physics.

High energy physicists always look for new ways to collect complex data quickly so that they engage in “designing, maintaining, and modifying” (p.55) their detector and simultaneously using it for their experiments. Different detectors designed to pursue a problem in any research group are mnemonic devices because detectors are viewed as the material embodiments of research groups and reveal that each research group has different modes of discovery and strategies to deal with noise in order to produce knowledge as well as to maintain doing good physics and a strong laboratory.

Social organization describes how a research group or the experimental particle physics community structures itself to continue to do lab work. The social organization of the laboratory associated with a research group’s history, its division of labor, and its strategy for discovering nature is shaped by building and rebuilding detectors. In other words, different detectors produce different research groups along with strategies for

making research equipment and building a career in physics. Thus, detectors are considered the “signature” of any research group.

The experimental particle physics community evolves by “training novices” (p.74). Transformation of novices into expert physicists or reproduction of physicists occurs through formal and informal education as well as through daily routines. Novices move from the textbook-based culture of undergraduate training into, “the coherent ground state” in which graduate students learn “good taste,” “good judgment,” and “creative work” and get the first “real feeling for physics” (p.82). When they become young physicists, they live in an increasingly oral, competitive, and aggressive culture, meaning that they start shaping their reputation and endeavor to be inside the “old boy club,” which in turn reproduces individualistic, competitive, and insular (male) physicists. The routine transition of graduate students and postdocs from one stage to the next is dependent upon relationships within networks. This transition allows them to be cognizant of the “hierarchy” (p.93) and envision their final place in the particle physics community. Yet, this process encompasses anxiety and time, success and failure, and frustration and hope at each stage of fifteen years-journey. The established physicists or full-fledged physicists even encounter these circumstances as to whether they still make contributions to the community and their work is obsolete or not.

The concept of time in the experimental particle physics community refers to the relation between “beamtime” (at the atomic scale which structures their study objects) and “lifetime” (at the human scale which shapes their careers, their detectors, and their ideas). Beamtimes and lifetimes converge in detectors where data are separated from

noise and signals from nature are received. In turn, this constitutes a discovery. Building detectors, transforming novices, gaining membership, and distinguishing data from noise all characterize the practice of physicists. These characteristics are shaped by “evaluative and persuasive talk” (p.118) inherent in the high energy physics culture.

It is obvious that the key descriptors depict how science is accomplished and practiced in these ethnographic texts. *Construction* is a joint descriptor in Latour and Woolgar and Traweek’s study, but they described *construction* descriptor in the context of science they studied in different ways. More specifically, *construction* in *Laboratory Life* referred to the process depending on stabilization of a statement into a taken-for-granted fact. *Construction* in *Beamtimes and Lifetimes* was to reflect the importance of machine building and rebuilding to constitute a discovery as well as to reproduce the community of higher energy physics. In the account of construction, *construction* descriptor in Latour and Woolgar’s study is equivalent to *agreements* descriptor because construction in Latour and Woolgar’s study depends on transformation of a statement into an object through adding, withdrawing modalities, and proposing new combinations operations on statement. Lynch’s *agreements* descriptor describes assertions and reassertions. These descriptors indicate negotiation processes to warrant the data as reliable.

Noise is another descriptor jointly used in Latour and Woolgar and Traweek’s study. *Noise* in Latour and Woolgar, and Traweek was portrayed in such a way that scientists needed to distinguish data from background noise in order to perpetuate doing scientific practice. Yet, in the account of *noise* descriptor, Lynch used *artifacts*

descriptor, but it gives the similar meaning. In other words, artifact is a trouble and problem as background noise that scientists encountered in their conduct. It depends on electron microscopic photography similar to noise depending on inscription device or detector. *Noise* descriptor in Latour and Woolgar and Traweek is corresponding to artifacts descriptor in Lynch's study in the sense that noise and artifacts are troubles, unexpected things or possibilities that scientists needed to resolve in order to perpetuate doing science. Therefore, distinction of data from background noise and artifacts in the three studies is a characteristic of doing scientific practice.

Overall, from descriptors used in each study, Latour and Woolgar's study is focusing more on formal and informal writing processes that occur after data collected from inscription devices as well as on operations on inscriptions or statement to obtain a taken-for-granted fact. Lynch draws on an archeology of artifacts by addressing agreements performed in shop talk and conduct. Traweek's main focus is the construction of detectors because detectors are determinant for perpetuating doing science as well as reproducing a community of physicists. In addition Traweek pays more attention on social organization of the laboratory addressing social network, hierarchy, masculine science, and community components compared to Latour and Woolgar, and Lynch.

Synthesis of the Three Ethnographic Studies

A close examination of the three interpretive studies reveals that the practice of science in different research laboratories has two converging constructs: material construct and discourse construct. By the material construct, I refer to the material

culture that scientists generate and use to perform their contextual practices in research laboratories. Yet, this material culture is not limited to a list of instruments (e.g., inscription devices, machines, detectors), but consists of inscriptions, statements, texts, and micrographs. The material culture is the primary actant that shapes scientists' further activities and credibility, and that transforms the community itself. At the same time, scientists as the primary actors design, build, and modify the material culture to reach their goal. Thus, mutual relationships and dynamic interactions between actants (non-human agents) and actors (human agents) characterize the practice of science in research laboratories (Latour & Woolgar, 1986).

In the case of the scientists in Latour and Woolgar's (1986) study, the products that technicians worked with were inscriptions, machine-generated texts that scientists treated as data and used to perform their operations in the process of fact construction. Their authorship would be shaped and they would acquire credit, or credibility in light of inscriptions (e.g., texts, graphs, or pictures) derived from the inscription devices. A new, better inscription devices result from the dynamic, mutual interactions between inscription devices, inscriptions, and scientists' cognitive operations in the agnostic field. Scientists in Lynch's (1985) study oriented their daily activities around dealing with potential troubles or artifacts. Troublesome artifacts were temporally emergent possibilities in electromicrographs or photographs. Scientists were dependent upon instruments (e.g., an electron microscope) that make visible troublesome artifacts resulting from procedural excesses and inefficacies. Identifying troublesome artifacts in the work of scientists did not determine their accomplishment. Instead, it led them to

further discuss whether micrographs parts are usable, analyzable facts, or artifacts. Scientists negotiated the use of microscopic montage excluding artifacts as data and determined the reliability of the data to accomplish their practical purposes. High energy physicists in Traweek's (1988) study met nature and brought their passion and knowledge together around machines (e.g., detectors). At the heart of this physics community were detectors that allowed physicists to distinguish noise to permit a legitimate discovery. Detectors were the material embodiments, signatures, and representations of research groups because they were considered as mnemonic devices through which physicists would understand a research group's history, its division of labor and the strategies taken to pursue a problem. High energy physicists built and rebuilt detectors to continue their contextual practices because new, better detectors would allow them to collect complex data quickly and analyze it effectively. At the same time, detectors allowed their community's evolution. Physicists established and sustained their community for the sake of detectors. Building new detectors was a stimulus for physicists to continue to make contributions and avoid obsolescence in the community.

From these three studies, I learn that the material culture of the laboratory is essential to pursuing scientific investigation and generating knowledge. Scientists in different labs may use approaches to machines or research instruments in their work; however, their dependence on those machines is similar in all three examples. Scientists in both Latour and Woolgar (1986), and Lynch's (1985) study trusted and credited research instruments in their works, as they produced inscriptions and micrographs to

generate scientific knowledge. While scientists in Traweek's (1988) study built and rebuilt detectors to perform their practices, considered them as mnemonic devices, and described how they designed, built, and modified them as the practice of science in their papers in addition to having trust and giving credit to detectors. For all scientists the absence of interactions with material culture would have severely altered their knowledge generation.

The 'rhetorical persuasion' (Latour & Woolgar, 1986), 'shop talk' (Lynch, 1985), and 'evaluative and persuasive talk' (Traweek, 1988) are examples of discourse construction in each of the three ethnographies used in the production of science. In Latour and Woolgar's (1986) study scientists' social endeavors to make statements about new information were iterative and interpretive in a sense that they performed operations of adding and withdrawing modalities on statements and formalized factual statements. In other words, the art of persuasion is the art of shifting statements from modalized positions to demodalized positions. Yet, they encountered claims of colleagues in regards to credibility and the reliability of their inscription devices as well as efficacy of facts. They dealt with their claims and arguments through rhetorical maneuvers in the writing of scientific texts (e.g., scientific journal articles). Thus, the point of their discourse was to establish facts.

Scientists in Lynch's (1985) study performed their discursive activities to manage the transformation of a disagreement into an agreement. They utilized discursive activities in two ways: *talking about science* and *talking science*. On one hand, discursive activities in the account of talking about science were performed through lab

tours and interviews with other colleagues. On the other hand, discursive activities in the account of talking science occurred with their colleagues when scientists attempted to modify their interpretations of microscopic montages, their plans for ongoing project, or their claims about reliability of data. Discursive activities in the account of talking science were associated with redescriptions, admissions of potential disagreements, and formulations of the original assertions and challenging statements until photographs were taken as data. Scientific and technical discussions were oriented around efforts to clarify and distinguish facts from artifacts or troubles on the basis of visual clues (e.g., analysis of discursive exchanges in conversations). Reaching agreement through discursive activities was shaped by social interactions, and it was a way to contribute to the production of results. Hence, the point of shop talk was to construct a collective understanding of the natural phenomena they were studying.

In Traweek's (1988) study, scientists performed their discursive activities associated with evaluative and persuasive talks. Discursive activities occurred during their work through oral communication rather than written communication. Talks were employed throughout designing, building, and modifying detectors and were used to persuade their colleagues to support their work. Through talk the community of physicists determined who will access detectors, who will be allowed to try to build new detectors and construct facts, who will be a particle physicist, and what a good detector is. Thus, the point of talk was to establish, access, and re-establish machines as well as to reproduce physics and its culture.

From the three studies, I learn that talk is an essential aspect in the practice of science and the knowledge generation process. Although the three studies of science considered the role of talk somewhat different ways, talk was iterative, interpretive, persuasive, and evaluative at the very edge of doing scientific work. Thus, talk is a link to communicate with scientists; it is a tool to persuade their colleagues; it is a determinant key to construct a taken-for-granted fact; it is a salient agency of transforming a community; and more importantly, it is inherent in the organization of a research laboratory.

Discussion

In the present study, I examined the three interpretive studies of science using meta-ethnography as a research methodology. The concepts that emerged in each case study were highlighted and translated for synthesis. The final synthesis was made for the potential audience who would understand, interpret, and reconceptualize. The synthesis reflected two converging themes among the three studies, though each case study individually had prolific aspects of scientific practice and the authors used different methodologies to understand the practice of science. Herein, I base a discussion on the laboratory itself and its importance in the selected ethnographies of science.

The laboratory is a system of literary inscriptions, the production of images, and the reproduction of a community. I elaborate these issues as the authors of these studies interpreted in their ethnographies. First, Latour and Woolgar (1986) describe the laboratory in regard to the relation between office space and bench space. Yet, central to the laboratory is the office of the researcher, reader, and author. In other words,

scientists perform their activities such as coding, marking, altering, correcting, reading, and writing in the office space. They juxtapose formal and informal writings with other artifacts (e.g., photocopies of articles, mail files, invoice book, lists of data) as well as with papers produced within the laboratory. Their activities in the laboratory result in the production of written documentations, data, and graphs. They construct their collective writings on the basis of output of inscription devices or texts by comparing and contrasting with other articles in the published literature. Thus, they conceive of the laboratory as a house of writing activity.

Second, Lynch (1988) describes the laboratory site as an environment for various technical specialties including particular instruments and facilities. These are distributed in the organization of the laboratory in regard to ongoing projects. The laboratory is the site that hosted a variety of research topics along with special technical methods. These aspects of the laboratory support obtaining data from distinct research instruments through available technical approaches. Thus, the laboratory is the site of technical specialties that characterize scientific work and produce natural objects (the material world) in laboratory research.

Latour and Woolgar and Lynch's studies focus on the material aspect of the laboratory and account for the constructive character of the knowledge generation process, though social interactions and collective works played a significant role. They focus on one knowledge area in one country and do not address the possibility of "the cultural diversity of knowledge" (Knorr-Cetina, 2001, p. 8235) that Traweek does in her anthropological study addressing the cultural side of the laboratory and the technological

side of the physics communities. She compared and contrasted these research laboratories with regard to the social organization of the laboratory, detector design and building, and leadership styles—all of which then characterized the community of physicists. For example, physicists in the laboratory in the U.S used their detectors for a short term, whereas high energy physicists in Japan designed and used durable detectors for their research purposes. In addition, the members in the SLAC community were always in contact with each other and shared their competence and resources to renew their next detectors. Since physicists in KEK worked at one detector and had less contact with others, they transferred the very long-lived detectors to the next generation.

The analysis of the three ethnographies of science reveals that a laboratory is not only physical space where artifacts such as instruments and technologies are generated and utilized to continue to do scientific practice, but it is also a social organization of a group of people sharing a joint enterprise, interacting with each other, actively engaging in their contextual practices.

Concluding Remarks

This study addresses scientific practice represented and portrayed in communities of science. It reflects the interpretive images of scientific practice employed in research laboratories, the knowledge generation processes, and the reproduction of scientific communities. I use the reports of the interpretive studies of science to inform the potential audience of this study in a way that challenges with the practice of school science and its social structure. I do so in three ways.

Professional science communities are grounded on the material culture that shapes and guides scientists' everyday activities. The material culture consists of research instruments and their development in order to continue to do science. The products of instruments are considered to be treated as data that plays a significant role in generating knowledge, and instruments themselves are playing a pivotal role in producing and reproducing the community of scientists. The material culture in research laboratories is not stable; instead, it is evolving as new technologies advance, communities renew, and scientists invest the credibility of their endeavors to generate knowledge. The material culture is dynamic and adaptive as scientists meet a block on their way to reach a common goal. Scientists' investigations depend on temporally emergent goals and plans, and this temporality guides them to develop the material culture in order to continue knowledge-producing practices.

In most school science classroom communities, the practice of science is dependent upon typically teachers and textbooks. Students are provided with laboratory instruments to conduct school science investigations in order to apply and verify knowledge represented by their teacher or in their textbook. The material culture in school science laboratory they face is stable. When new technologies appear in the industry, curriculum makers enforce schools to purchase and use them and then students are given them to do their investigations. School science community's members, particularly students' goals and plans include memorizing and acquiring the knowledge taught, succeeding in exams, and being ready for the next year's concepts. A reasonable gap between the school science communities and the professional science communities

with regard to the material culture emerges. To narrow this gap, a more realistic representation of science communities should be translated into school science classrooms. To do so, the potential audience of this study should adapt and translate perspectives emerged from professional science communities. For example, they should encourage students to develop and pursue their own goals in a classroom community of practice. Students should be motivated to build and re-build specially designed research instruments to collect data with the reference to their research question. Data can be analyzed and argued among students as to whether they can rely on data and then they can generate a meaning out of the data.

Discursive activities in professional science communities are to generate scientific knowledge as well as to reproduce communities. To obtain a taken-for-granted fact, to distinguish data from artifact, and to evaluate claims and findings depend on discourse constructions within the community of scientists. Discursive activities are determinant for the credibility and reliability of their research instruments as well as efficacy of facts. Their social endeavors to make a decision about the quality and reliability of microscopic images as data, for instance, depend on mutual negotiations and scientific and/or technical discussions. Discursive activities are both evaluative and persuasive. Communications among scientists guide and shape their next step to conduct their investigations. Interactions emerge in social network through which scientists decide who will have an access to research instruments as well as to move to the next stage in their academic career. Discourse constructions allow scientists to pursue their

investigations, construct the social organization in the laboratory, and generate knowledge in communities.

In most school science communities the everyday activities of students are not similar to those scientists perform in professional science communities. School science discourse activities are confirmative and informative rather than evaluative and persuasive. Communications are employed between students and their teacher in such a way that the teacher initiates a question; a student responds; and the teacher evaluates or provides feedback. Collective discourse constructions among students are rare compared to the whole class discussion where the teacher dominates in the discourse of school science practices. Translating the science communities' scientific discourse into school science communities' discourse is a means for the potential audience of this study to revise the discourse practices in science classroom communities.

As portrayed in Traweek's anthropological study, high energy physics community is a complex and evolving system that hosts many individuals regardless of age, education, experience, and expertise. There is a status hierarchy among members of high energy physics community. She reveals that heterogeneity exists in the culture of high energy physics that includes novice physics students (e.g., undergraduates), doctoral students, postdocs, experts, full-fledged physicists, and so on. This in turn generates a social network among the members to move to the next stage in a community of physics. The physics community renews and reproduces itself, as novice physics researchers become expert over time. The training process contributes to this transition. There is an expectation that young physicists should contribute to the

community by building new detectors and through knowledge generation. Nonetheless, in most school science classroom communities, there is a status hierarchy between the teacher and students. They have differences in regard to knowledge, experience, and age. Such differences can be used to contribute to their research and learning. School science community can develop heterogeneity that includes students at different levels of knowledge and competence. To do so, its members should be encouraged to pursue an unknown and given an opportunity to develop their own ideas and materials to perpetuate to do science. Heterogeneity in school science community will be a stimulus for students and teachers to establish mutual interactions and transform novice students into more experienced ones. This cultural transformation process will contribute to the reproduction of school science community.

CHAPTER III

PORTRAYING THE DISTINCT CHARACTERISTICS OF A SCIENTIFIC-ENGINEERING COMMUNITY

Overview

This study explored the culture of a scientific-engineering research community and the socio-cultural characteristics of the community members' interaction. How the community members worked in collaboration as they conducted their research, how they negotiated and mutually agreed upon as they interacted and communicated with one and another and what they have learned through the process of these interactions were the questions. The study participants comprised two university faculty, one visiting scholar, and seven graduate students. The community members were observed over two months, and interviewed formally and informally during the same time. Data were analyzed using the constant-comparison method and ethnographic data analysis methods. Findings reveal that different working styles of the two faculty members lead to the formation of different research groups. Mentorship is a catalyst for enculturation process, and it is on the trajectory of becoming an engineering faculty. One recommendation coming from this research is to use the distinct features of the scientific-engineering community in such a way that STEM teachers work with the faculty member with distributed group structure in order to capture her working style that maintains learning, coordinates projects, and manages research and experience them for use in their classrooms.

Introduction

Research in the learning sciences focuses on the cognitive, epistemological, and socio-cultural characteristics of scientific and engineering research communities in their efforts to improve Science, Technology, Engineering, and Mathematics (STEM) education. Science learning is getting familiar with and accustomed to the practices that scientists perform in their everyday lives rather than purely learning about scientific knowledge or science process skills. This shift has helped students to engage in the process of knowledge construction through authentic tasks that investigate real-world contexts and conceptualize scientific work and enterprise. Thus, research in the learning sciences continues to elicit a variety of aspects of scientific and engineering communities, which in turn contributes to the efforts in designing STEM learning environments.

In order to document a more realistic representation of scientific and engineering research communities, learning scientists have turned to exploring research teams' everyday practices using ethnographic and anthropological lenses in the research laboratories (Buxton, 2001; Nersessian, 2006, 2009; Vinck, 2003). These lenses allow us to "observe, record, and engage in the daily life of another culture" (Marcus & Fischer, 1999), explore the process of 'knowledge-in-the-making' in the laboratory (Beaulieu, 2010), and conceptualize sense making and identity in science practice (Osbeck, Nersessian, Malone, & Newstetter, 2011). Central to this ethnographic research is the idea of closely studying engineering scientists and researchers' work in day-to-day lives within a social context, understanding and exploring the distinct characteristics of

scientific and engineering work through ethnographic eyes and ears, and providing a holistic view of a scientific-engineering community (Faubion & Marcus, 2009; Hammersley & Atkinson, 2007).

Theoretical Framework

The theoretical framework of this study is derived from the literature on (a) social studies of scientific and engineering practices and (b) the notion of communities of practice.

Social Studies of Scientific and Engineering Practices

Science in social context has been invoked by Thomas Kuhn's (1962) essay "The Structure of Scientific Revolution." Kuhn (1996) characterized the scientific practice into two means: 'normal science' and 'revolutionary science'. In his essay, Kuhn (1962) rejects the linear progress of science and points out the dynamic aspect of science by focusing on the activities scientists perform in scientific research. Kuhn's ideas set the stage for further studies in science and technology to explore whether "scientific communities are organized around ideas and practices instead of ideals of behavior" (Sismondo, 2010, p.22).

Social studies of science and/or technology draw on anthropology and sociology as well as cultural studies and cultural history of science (Weinstein, 2008). These studies reveal that different insights into understanding of science, technology, and their relations with society have evolved over time. Among them are the Mertonian norms (Merton, 1973), the Strong Programme (Bloor, 1991), and Laboratory Studies (Knorr-Cetina, 1995). The Mertonian understanding of science helped us understand the

sociological account of scientific knowledge and the system of science (Kelly, Carlsen, & Cunningham, 1993), yet it did not address the products of scientific practice (Restivo & Croissant, 2008). It did not properly explain science in social context according to the pioneers of the Strong Programme (e.g., Bloor, 1991; Barnes & Bloor, 1982). The pioneers of the Strong Programme have underlined the Kuhnian thought of the scientific community and cultural variations in the scientific activity (Vinck, 2010). They focused on the relationships between scientific and engineering work and pointed to the material cultures of science and technology (Sismondo, 2010).

Laboratory Studies study science and its various aspects. Laboratory Studies explore the characteristics of the knowledge generation process within the science and/or engineering communities. These studies view the physical laboratory itself as a salient agency for scientific development (Knorr-Cetina, 1995; Vinck, 2010). Yet, laboratory is a zone where individuals and research groups produce rules to construct the organization of laboratories (Louvel, 2005). Osbeck, Nersessian, Malone, and Newstetter (2011) view the laboratory as an important site to understand and explore cognitive, social, affective, material, and other dimensions of social activities embedded in the culture of a single laboratory and even multiple laboratories (e.g., Buxton, 2001; Traweek, 1988). In other words, research laboratories are not simply physical spaces where instruments and specific technologies are generated and utilized to perform scientific practices, but are complex systems where a group of people shares a joint enterprise, actively engages in everyday activities, and mutually interacts with each other (Osbeck et al., 2011; Wenger, 1998). Research laboratories are epistemic cultures or cultural entities, and provide an

“enhanced environment” (Knorr-Cetina, 1999, p.26) where scientists and/or engineers create order out of disorder and constitute a discovery (Latour & Woolgar, 1986; Traweek, 1988). Thus, laboratory studies elucidate science as investigation, work, enterprise, and culture (Weinstein, 2008).

Laboratory Studies help us draw a more realistic picture of real science. Scientists perform agnostic activities to battle for knowledge generation in the scientific communities (Latour, 1987). Present and past members of a scientific community socially construct the meaning and understanding of terms, ideas, and actions through social negotiations and communications (Brown, Collins, & Duguid, 1989). The activities and actions scientists perform individually and collectively in their communities are attributed to “real science,” and it is interchangeably used with “authentic (professional) science” (Barab & Hay, 2001; Berland, 2011; Roth, 1995). Moreover, authentic science is viewed as a complex activity (Chinn & Malhotra, 2002; Erickson, 2005) that “requires elaborate procedures, expensive equipment, specialized knowledge, and advanced data analysis” (Thompson & Parrott, 2003, p.1). The commitments scientists and science practitioners have made to pursue an unknown take place in a picture of real science (Edelson, 1998). Real science is taken into account within the qualities of good scientific practice, such as, competence, work ethic, and continuous interest in science (Buxton, 2001).

Additionally real science is considered within the dual nature of agency—social and material world as well (Pickering, 1995). Pickering points to the phrase “mangle of practice” that delineates the interplay between human and material agency by

emphasizing intentions, plans, and goals along with the interests of individuals and constraints. In this view, once science and engineering researchers encounter a resistance, they need to accommodate and solve it in a way that ends up with a new machine or new knowledge. According to Pickering, scientific investigations are not predictable, meaning that scientists and engineers develop temporally emergent goals to perform practices in science and engineering communities. Thus, laboratory studies are a means for us to explore the distinct characteristics of scientific practice in scientific communities as well as to portray a more realistic picture of real science.

Many researchers have shed light on engineering practices within cognitive, social, cultural, and material contexts (e.g., Hackett, Amsterdamska, Lynch, & Wajcman, 2007; Nersessian, 2005, 2006, 2009; Latour, 1987; Sismondo, 2010; Vinck, 2003, 2010). Hackett et al. (2007) in *The Handbook of Science and Technology Studies* reviews the scholarship of the multifaceted dimensions of science, technology, and their interactions with society. Similarly, Sismondo (2010), in his essay entitled *Introduction to Science and Technology Studies*, provides a lens for understanding science and technology as discursive, social and material activities. Vinck (2010) draws attention to the emerging engineering sciences that are set between theory and practice. Vinck points out that combining theory and practice is a way for engineers to develop their own methods and instruments through which scientific knowledge is used and produced.

Engineering related laboratory studies are associated with technological practices (Vinck, 2003). In the essay, *Everyday Engineering: An Ethnography of Design and Innovation*, Vinck and his colleagues delineated the everyday work of engineers and

technicians with regard to design, management process, and innovation. They focused on the socio-technical complexity of an engineer's practices and tool-design process. They raised questions about the relationship between human and non-human agents. In order to understand what engineers do, they explored their design activities, described the social, cultural and technological aspects of their practices, and examined their writing practices.

More specifically, Nersessian (2009) studied engineers' practices in regard to designing, building, and experimenting with physical simulation models and sought to understand and interpret how model-based simulation practices are playing a role in the generation of knowledge and technologies in the biomedical engineering research laboratories. In her study, research laboratories were considered to be evolving cognitive-cultural systems where scientists and engineers perform their knowledge-producing practices (Nersessian, 2006). Based on the notion of distributed cognition, Nersessian (2009) articulated model-based reasoning within a cognitive-social-cultural system. She reported that devices and model systems that engineering scientists generate and use were cognitive artifacts. These artifacts referred to the material culture of a community. In the present study, I study scientific-engineering practices of a complex system (Latour, 1999; Nersessian, 2005) similar to "the mangle of practice" that encompasses human and non-human agents, social arrangements, and cultures (Pickering, 1995). Thus, I aim to find out and utilize the different perspectives of the scientific-engineering community to conceptualize how learning and research is sustained in such a community.

Communities of Practice

Communities of practice have historical and social roots with the discourse of the notion *Cognitive Apprenticeship* discussed by Brown et al. (1989), and *Situated Learning: Legitimate Peripheral Participation*, discussed by Lave and Wenger (1991). Brown et al. (1989) used the term cognitive apprenticeship to emphasize that learning occurs when individuals are engaged in authentic tasks or real-world problems. Learning advances through collaboration and social interaction. Lave and Wenger (1991) point to participation in communities of practice where a newcomer goes through trajectories and needs to acquire knowledge and gain some skills in order to be a part of the community.

The concept of communities of practice concentrates on the sociocultural transformation. Individuals develop identities in the context of a shared practice rather than replicating others' performances as they learn (Lave & Wenger, 1991). Communities of practice provide a context in which a group of people engage in a joint activity, communicate with one another actively, and mutually share knowledge, practice, and beliefs with other members (Wenger, 1998). Likewise, Wenger, McDermott, and Snyder (2002) summarize that "a community of practice is not just a website, a database or a collection of best practices. It is a group of people, who interact, learn together, build relationships, and in the process develop a sense of belonging and mutual commitment" (p.34). In addition, mutual engagement, joint enterprise, and shared repertoire are interrelated constructs that explain the social processes and the identity transformations in a community (Wenger, 1998).

Communities of practice exist everywhere including research laboratories and centers or institutions (Wenger et al., 2002). At a research center, a group of science and/or engineering researchers with their students perform legitimate scientific practices through negotiation and participation. Newcomers acquire knowledge and skills that a community's members use or generate to continue their practices and become a member of the research team. A research center's members establish communication structures and connections with other communities and share their tools and experience with each other. Their mutual engagement and collaboration help them sustain their shared goal. In the present study, I delineate a complex system of the scientific-engineering community by highlighting research community members' interactions and communications, their normative practices, and learning and research processes to depict the emerging attributes of communities of practice.

In an effort to understand the distinct characteristics of a scientific-engineering community, I posed three research questions: (1) What are the distinct characteristics of the community?, (2) How do the community members (the university faculty and the graduate students) sustain learning and research in their community?, and (3) How do the community members operationalize their scientific and engineering practices within their community?

Methods

Design Procedure

Ethnographic study techniques are a means for studying social organizations and learning a culture of individuals and research groups, for example, a research laboratory. We talk to individuals about their beliefs, experience, and thoughts about their contextual practices, attend their group meetings, and then obtain etic perspectives to delineate their culture. Therefore, in this study I employed participant observation, interviews, and field notes to implement the course of research on chemical engineers performing computational biology practices through computer-based modeling and visualization at a Research-1 University in Turkey. The study's aim was to explore and document the distinct characteristics of the scientific-engineering community, the contextual practices engineering researchers perform, and efforts and strategies to sustain their research and learning through ethnographic study methods.

The Setting

This study took place in the research center, "Biological Complex Systems Research Center (a pseudonym)." It was selected for this study purposively because I as a researcher was curious to learn from a group of people including faculty and students (e.g., post-doc, graduate and undergraduate) all of whom were pursuing a common goal to generate new knowledge. The center was self-sustained, and it was convenient for me to reach. My first impression about the center encouraged me to contact the director and plan conducting my study in the center.

My primary visit to the center happened in Summer 2010. Before my visit, I had studied it on the Internet. I learned that there were a list of individuals with their departments' names, their roles, and titles. I had an image in mind that there would be a laboratory with benches, scientific equipment, and materials, and I would encounter a messy and dirty research setting where experiments were conducted because I was taught that science is done experimentally and scientists conduct their experiments in their laboratories where a disorder exists. However, there was no laboratory itself in the center; instead the center was comprised of several offices. In the center, researchers were given office spaces to use and work in. While faculty members were given individual offices, graduate students, especially doctoral students were working together in the same, one big office. Masters and undergraduate students were welcome to sit and work at the entrance of the research center. It appeared that there was a hierarchy among the center members in terms of the space allocation.

The research center also had other offices for visiting researchers (either international or national). In the offices, each individual researcher was provided with a computer desk to work on their investigation. Since the center was not a laboratory setting, individuals spent their time sitting in front of their computer and conducting their investigations with support provided by a central supercomputer called "Server." The center had a designated space for the supercomputer and a conference hall as well. Their laboratory equipment was also in the center. Another common space was a kitchen that the center members used to have coffee breaks and short conversations regarding their ongoing research and daily life.

The center hosted two core faculty members, one post-doc student, eleven graduate students (five doctoral and six masters students), and senior undergraduate students who had taken the core faculty's courses and have been interested in doing computational biology practices. In the analysis the primary focus was on the data from the two university faculty, two doctoral students and five masters students. Another participant of interest was an adjunct faculty member (a visiting scholar). She was a former graduate student at the research center. She had a significant involvement with the community members' practices and the overall socio-cultural context of the center. All three faculty participants were the graduates of the same major in different years.

One of the two core faculty members was the research center's director and a chemical engineering professor. The other one was the vice-director of the research center and also a chemical engineering professor. Both faculty members have been in the research center for the last ten years. The adjunct faculty member in this study had worked with the former director of the research center and she is currently a professor at another university. There were two doctoral students with a chemical engineering background. Both had more than four years of experience at the research center and held master degree in chemical engineering. Five masters students were pursuing degrees in chemical engineering. Four of the five masters students had chemical engineering backgrounds, and one of them had both a chemical and genetic engineering background.

The research center hosted two staff members assisting the faculty members in the administrative work for the research center. The center also hosted many national and international researchers. The center members called them "Collaborators." These

researchers visited the center in different times throughout a year. Collaborators were not expected to have similar backgrounds with the center members. Instead, collaborators with different background were considered as a stimulus for the center members because the members shared with them a common goal and benefited from their competence, knowledge, and experience to perform their contextual practices.

In this study, names of the research center members have been changed in an effort to protect the confidentiality of the individuals. Their names are all pseudonyms.

Data Collection

In this study, I acted as a participant observer and employed ethnographic data collection methods—participant observation, field notes, formal and informal interviews, and documents and artifacts (Creswell, 2007). The primary data collection sources were participant observation, and formal and informal interviews. The secondary data sources included the participant observer's daily journals, field notes, and documents and artifacts. The participant observer conducted observations when the members of the research center worked, interacted with each member, attended meetings, and had their coffee breaks and lunch. Throughout the research, the participant observer employed three kinds of observations: (a) descriptive, (b) focused, and (c) selective. These observations were the classic tradition of participant observation (Angrosino & Rosenberg, 2011; LeCompte & Schensul, 2010). Descriptive observations were to understand a social situation (e.g., the research center). To organize descriptive observations, I started to ask, "What's going on at the research center?" I followed focused observations to answer another question, "What kind of roles do members take

on at the center?” To narrow my investigation, I made selective observations. I asked, “What differences can I see among the research center members?” My participation at the beginning was limited and at the non-participant level. It turned out to be a passive-participant level at the end of my observations.

I conducted formal interviews with two faculty members, two doctoral students, five masters students, and the adjunct faculty member in person at the research center. All interview questions were open-ended and semi-structured. I asked emerging questions as appropriate during the conversation. I constantly revised my list of interview questions. Informal interviews usually took place at the research center during coffee breaks and lunch. Both formal and informal interviews were audio-recorded. Yet, informal interviews with two members were not audio-recorded because they did not want me to record their voices. Thus, I took notes in regard to their responses.

I wrote daily journals to describe and interpret the cognitive, social, cultural, and material dimensions at the research center. My fieldwork diaries including each day’s happenings, personal feelings, ideas, and impressions in regard to those events were to be crystallized with the primary data sources (Creswell, 2007; Richardson & St. Pierre, 2005).

Data Analysis

To analyze a variety of data I collected; first, I used ethnographic data analysis methods (LeCompte & Schensul, 2010, Spradley, 1980). Ethnographic data analysis methods were employed throughout the observations simultaneously. These methods consisted of three phases: domain analysis, taxonomic analysis, and componential

analysis (LeCompte, 2000; Spradley, 1980). As mentioned earlier, the descriptive observations were used to understand who are the people, what kind of activities they do, where they work and study, and what the goal to accomplish is. I analyzed the descriptive observations to identify domains.

The domain analysis has three elements: (a) cover term; (b) included term; and (c) semantic relationship (LeCompte & Schensul, 1999; Spradley, 1980). For instance, to understand community members' routine activities, I noted, "Extracting a protein from the Protein Data Bank (PDB) is a way to do their routine investigation." In this example, the whole sentence represented a domain. *Extracting a protein from the Protein Data Bank (PDB)* was an included term; *is a way to* represented semantic relationship; and *continue their routine investigation* was cover term. Based upon the domain analysis' findings, I employed the focused observations followed by the taxonomic analysis. In other words, I looked for the other routines that the center members did. For instance, reading the relevant literature, writing algorithmic functions, creating computational protein design, and running computational simulations were among the other routines to do. Then, selective observations were analyzed and clustered using the componential analysis. For instance, I concluded that there were daily routine works that the center members do to continue their investigation and understand protein-folding dynamics. From the three-phase ethnographic analysis, I generated a domain (e.g., kinds of research groups) that included individuals, their roles and responsibilities, and their routine activities.

A constant-comparative method (Glaser & Strauss, 1967) was used to analyze the data coming from interviews, field notes, and artifacts. All formal interviews were transcribed and merged with the secondary data sources. Open and axial coding was followed by selective coding to analyze the transcription and field notes verbatim (Strauss & Corbin, 1998). Emerging themes from the analysis are presented in the findings section.

Findings

I organized findings along four dimensions: (1) reconfigurations of research groups; (2) representations of roles and responsibilities; (3) qualities of doing scientific-engineering practices; and (4) the emergence of a community of practice.

Reconfigurations of Research Groups

The faculty members' working styles were determinant for the reconfiguration of different research groups. In the center, the members have been involved in ongoing national and international projects. Each project referred to a group of individuals engaging in a scientific-engineering work, mutually interacting with each other, and forming a social network under a faculty's supervision. Each faculty member displayed different working styles to continue to do their research. This difference did not impact research groups' research interests and methods or techniques to use, but different interaction and communication structures emerged. Faculty's working styles were categorized into two types: (a) *centralized* and (b) *distributed*. The director of the center, Nergiz developed her interactions and communications with her research group members in the centralized style. She had direct contact with senior undergraduate and

graduate students, and internal and external collaborators with whom she worked. She preferred working with them one-on-one regardless of their expertise, experience, and competence.

In contrast, the vice-director, Alara has had the close friendship with Nergiz for many years, but she organized and established a more complex communication structure with her research group members. In her research group, masters students and doctoral students always worked together. Sometimes visiting faculty members and international collaborators joined her research group. Her working style yielded different types of interactions and interrelationships over time such as student-student, faculty-students, and faculty-faculty.

The interactions among the individuals in each research group and the groups are illustrated in Figure 1. Nergiz and Alara developed different interaction structures in the groups, though they were always in contact with one another. On one hand, Nergiz's research group consisted of three doctoral students and three masters students, and national and international collaborators. Each student worked independently from each other, but they each had a connection with Nergiz. In the centralized structure, Nergiz was the center of action. She established one-on-one interactions with each student to monitor each student's work, manage research process, and support student's learning and development through advising, sharing ideas, and providing feedback. The main reason to build her research group in such a structure was related to her researcher role and accountability in the center. Nergiz was the director of the center and had the administrative accountability. She held the view that she always sought funding to

continue to do research and cultivate engineering researchers. That view motivated her to collaborate with both national and international researchers and build scientific partnerships. Within this pragmatic view, she acted in an unstructured and flexible manner that allowed her to conduct her research and at the same time interact with her research group members on one-on-one basis through meetings and discussions.

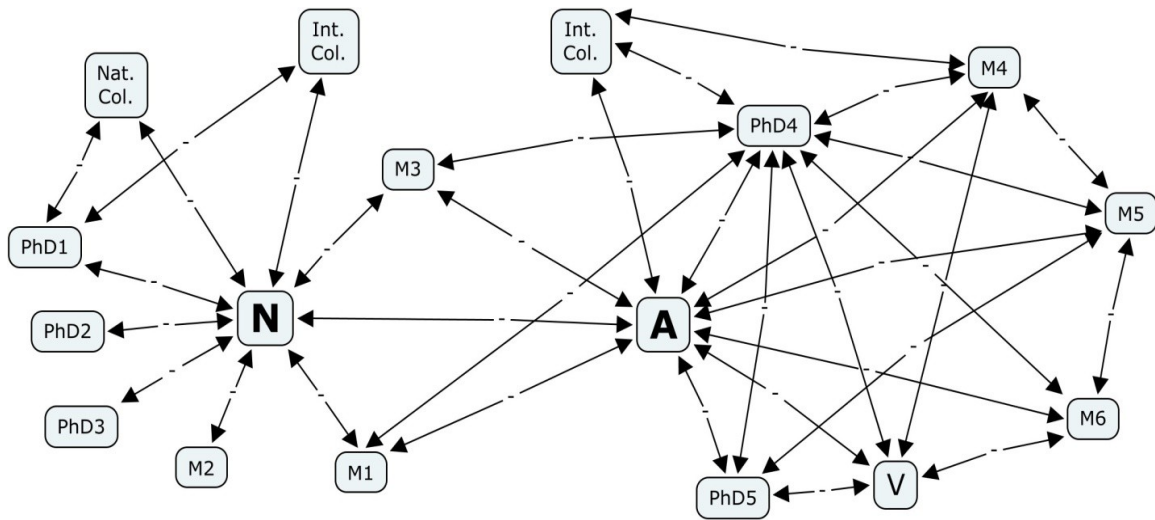


FIGURE 1 Connections among individuals in the research groups.
(N: Nergiz; A: Alara; Nat. Col.: National Collaborators; Int. Col.: International Collaborators; V: Visiting faculty member; M: Masters student; PhD: Doctoral student)

In the analysis, the arrows were identified that connect the individuals and were illustrated in Figure 1. For example, the connections between PhD1 and international collaborators, and N referred to their collective works at the international basis. At the same time, the connections between N, A, and M3 referred to the collaboration that

emerged in the center to conduct their investigations at the national basis. However, there were no connections between individuals in Alara's research groups, for instance, between M1 and M2, PhD2 and PhD3, and M2 and PhD1, which indicated no interaction developed among these members.

On the other hand, the Alara's research group was made up of five masters students and two doctoral students, and visiting faculty members (international or national collaborators). More interactions occurred in the distributed structure compared to the centralized structure because she wanted her research group members to develop social relationships to learn from each other. The distributed working structure evoked several sub-research groups within the Alara's research group. For example, the connections between PhD4, A, and international collaborators were that they have been involved in the international project and shared their mutual goal to accomplish. The connections between A, V, PhD4, and M4 referred to the national basis project where they interacted with one another. Each member in a group worked in a collective manner and had weekly meetings to discuss their individual projects. Yet, there were no connections between M1 and PhD5, and M1 and M3, which indicated no interaction developed among these members.

In the distributed working structure, Alara was not the center of action. Each masters student was assigned to conduct her own investigation. Masters students were encouraged to work with doctoral students, who scaffolded performing their investigation and mentored them. For example, the connections between PhD4 and M4, PhD4 and M5, and PhD4 and M6 referred to such scaffolding and mentoring process in

Figure 1. Masters students first asked to mentors when they needed to handle with any problems, issues, and decisions. Next, they shared with Alara their temporal solution or an idea originating from the mutual interactions. The main reason for Alara to build such a structure in the research group was simply to reduce her workload. She also wanted to create a synergic working environment in which her research group members could continuously interact with and learn from each other. In her interview, Alara stated:

It is not possible to deal with such work alone...there are 3-4 ongoing projects at the same time....it is not possible to do such work while teaching and having other responsibilities at the same time...interactions in pairs or in a group of 3 or 4 bring synergy on the table...It increases motivation to work...doctoral students and master students become a part of a chain...instead of informing and telling newcomers about the center, its purpose, research, and skills, working with a doctoral student is beneficial for them because they become shy at the beginning and ask every detail in mind. (Interview August 12, 2010; translated by the researcher)

The different working styles stimulated Nergiz and Alara to adopt and establish different interaction and communication structures with collaborators. On one hand, Nergiz preferred to work with her collaborators in a one-on-one basis. As illustrated in Figure 1, she occasionally included her doctoral students (e.g., PhD1) in her communication with collaborators. She did not ever include her masters students in such a communication. On the other hand, Alara constructed her communications with

international and national collaborators (e.g., a visiting faculty member) in a way that comprised doctoral students and masters students.

Despite this difference in the establishment of communications with collaborators, their collaboration with outsiders turned out to be an opportunity for both their doctoral students (e.g., PhD1 and PhD4) and the faculty members. For instance, PhD1 and PhD4 in Figure 1 communicated with international collaborators and PhD5 communicated with national collaborators (e.g., a visiting faculty member). PhD1 and PhD4 had the opportunity to visit collaborators' research centers or laboratories. They worked as an apprentice at the elbow of collaborators and learned new techniques and insights from them as well as shared with them the techniques or methods generated and used in the center. At the same time, PhD1 and PhD4 were mediators for Nergiz and Alara to maintain their mutual communications and research with collaborators. This circumstance helped them form a social network that included researchers working experimentally and computationally in different disciplines. This social network triggered a synergy to generate, coordinate, and implement interdisciplinary projects.

Representations of Roles and Responsibilities

Faculty member as researcher, administrator, and broker. The interdisciplinary aspect of the research center motivated Nergiz and Alara to establish different roles and divide responsibilities. Both Nergiz and Alara were tenured at the university and expected to teach undergraduate and graduate courses. Both worked as professors in the department of Engineering, but they had researcher roles to carry out computational biological engineering activities in the center. Because they were the only

faculty members working in the center, they divided their roles and responsibilities to manage the organizational and administrative works of the center. Even though Nergiz was officially the director and Alara was the vice-director, both were more inclined to make decisions together in regard to the epistemic, cognitive, and material aspects of their work as well as the organizational dimensions of the center (e.g., designing a collaborative, dynamic research, and learning environment). Thus, they developed researcher and administrator roles as they taught university level courses.

It was largely accepted that different disciplines or communities have started to intersect with each other, and boundaries started to blur among the disciplines (NRC, 2003). In this view, Nergiz and Alara developed broker roles. They built connections across the other communities. Since they have been performing their work within the interdisciplinary context including mathematics, physics, chemistry, biology, and engineering, they needed to collaborate with other researchers in different communities. This led them to develop multi-memberships (Wenger, 1998). The rationale behind adopting the identity of broker was to build scientific partnerships; they utilized and applied different methods and techniques (e.g., machine learning) generated in different communities into their practice. They sustained the identity of broker through mutual engagements with their collaborators in different communities through annual conferences, personal visits, and teleconferencing. Their continuous participation in communities provided them with the opportunity to learn new insights, ideas, knowledge and techniques to resolve their engineering problems. Thus, the developed broker role built a bridge between the social practices of different communities (Wenger, 1998).

The role of broker provided opportunities for the two faculty members in the center to coordinate their administrative work and research, and to align their goals and interests with scientific-engineering communities through mutual engagements. Learning a variety of perspectives from other communities helped them perform their computational biology practices, gain time management skills, and work effectively. Participation in different communities motivated them to construct a collaborative partnership. Such partnership was considered as a milestone to generate new research topics, develop a joint goal, and contribute to the generation of new knowledge through mutual negotiations.

The director conceived of their interaction, collaboration, and social relationship with other researchers as “scientific marriage.” In her interview, Nergiz stated:

Such a scientific marriage is like a relationship. Our purpose is to do work together. It is like “Many hands make light works.” More importantly, our work is not something that a solitary person can handle. You cannot learn everything. It is not possible that you can do what you want to do alone because you have to spend your time and energy for one thing that you know at a time in order to better understand and perform it. In other words, you need to find someone who can contribute to your work with her background, expertise, and competence. (Interview August 10, 2010: translated by the researcher).

As mentioned in the above quote, scientific marriage was dependent upon sharing roles and responsibilities, and respecting and trusting each other’s expertise, competence, and perspectives. Building a scientific marriage contributed to their efforts

in getting project grants and supported learning and development of novice engineering researchers. Thus, the broker identity played a major role in establishing collaborative partnership and maintaining research and learning in the center.

Doctoral student as researcher and mentor. The different working styles of the faculty members resulted in two doctoral students taking on different roles and responsibilities. On one hand, Nur, a doctoral student, worked under Nergiz's supervision. Her role and responsibilities had pedagogical and researcher dimensions. For instance, she was a teaching assistant teaching undergraduate chemical engineering courses. She advised and scaffolded undergraduate students with whom Nergiz worked through one-on-one interactions. She was engaged with computational biology practices. She was motivated by Nergiz to write project grants in order to sustain research. She collaborated with other doctoral students to write grant proposals for big scale projects whereas she preferred writing grants for small-scale projects by herself. Thus, Nur established one-on-one interactions to communicate with undergraduate students and initiated collaborations with other individuals to continue research in the center. In her interview, Nur stated:

In terms of research, I am a doctoral student and standing where I am as a doctoral student. I do not have a joint work with someone else. This was similar to pursuing a master's degree. If you are a doctoral student, masters students come by and ask you a question. You help them answer their questions ... In addition, I do write grants for small-scale projects by myself and for big scale projects with other doctoral students. In terms of teaching, I am working with

Nergiz to help her organize her courses, grade students' assignments; simply, I help her for course preparation. (Interview July 9, 2010: translated by the researcher).

On the other hand, Ozlem was a doctoral student who worked under the auspices of Alara. She did not have any teaching assistant responsibility as Nur had, but she was encouraged to help newcomers (e.g., masters students) adapt to the culture of the research center community. She organized weekly meetings with each newcomer to monitor their investigation and performance. She spent time lecturing them, sharing, and discussing with them the background information and skills that newcomers needed to do their investigation. In turn, she helped Alara coordinate ongoing projects with newcomers, and accomplish engineering tasks in her research group. At the same time, this process provided opportunities for developing a mentor role. She experienced organizing, conducting, and managing projects. In her interview, she stated:

Somehow this helps me out; whether working with the group or individually one-on-one is better or not...I was able to compare these two to decide whether to work in small groups or through one-on-one interactions. This is an important lesson for me because I will be a faculty in the future; I need to learn how to best coordinate my projects with my students. Working with many newcomers, and get them involved in their projects is not easy. You need to find a working method to deal with it. If you have a responsibility to do so, you have to guide them [students in the project] in their research. (Interview August 10, 2010: translated by the researcher)

In addition, helping newcomers' projects was the opportunity to engage in their project and learn new research topics. Yet, the main reason that she worked with them was that she was the one who was familiar with the methods or techniques that newcomers needed to learn and Alara kindly asked her to do so. Ozlem shared with newcomers her research experience through their mutual communications and negotiations, which contributed to their learning and research. Ozlem followed Alara's working style in the sense that she was not the center of newcomers' actions, but she scaffolded their learning by organizing the weekly meetings and establishing interactions with newcomers. Thus, she exhibited researcher and mentor roles that were a social route to becoming an engineering faculty member in the near future.

Masters student as researcher/learner and intermediate member. Mentors and advisors considered their masters students as newcomers as well as researchers. Most of the masters students were chemical engineering majors. However, some of them came from different institutions where they were often immersed in conducting chemical experiments and designing reactor models in the traditional ways. When they came to the center, they encountered a different culture where the center members were involved in project-based learning and research process, and engaged with computational biology research. Masters students had little or no experience with scientific-engineering research on protein folding dynamics with computer-supported modeling and visualization. They needed to learn content knowledge and computer programming language and gain skills to perform computational investigations. In that regard, they were encouraged to take the relevant courses supporting their research at the center. At

the same time, they were assigned to lead the national projects under the faculty's supervision and applied the theoretical perspectives into their practice. Leading a project was a tool for them to gain accountability over time, which in turn increased their confidence and ability to regulate their learning and research. Thus, masters students developed learner and researcher roles in a way that contributed to their learning progression, gaining competence and experience, and a capability of doing a research.

Masters students were also considered as intermediate members who would leave or stay and continue to do scientific-engineering practices. Their mentors and faculty members had various expectations from them. For instance, mentors expected them to learn common knowledge and gain skills that the center members use so that they would be familiar with the center's norms, move from peripheral to center of the community, and contribute to ongoing projects. In her interview, Ozlem stated:

When Tolga and Dilek came to the center, they had no experience with programming and protein folding dynamics. I talked to them about what topics we study at the center, how we write the scripts, what are our working conditions... simply to familiarize them with the norms and practices in the center. I monitored their progress because you want to see the outcomes of your efforts and time that you put into. (Interview July 19, 2010: translated by the researcher)

The faculty members considered masters students as part of knowledge generation process because masters students as researchers did the literature review, collected and analyzed the data, and generated predictive protein structures through modeling under the supervision of their professor and mentor. Masters students were in

active interaction and communication with their research group members. Thus, the faculty members expected them to have at least one publication when they graduated or soon after graduation. Publishing was not mandatory for the masters students. Yet, they were encouraged to do so if they would pursue doctoral degree as the next step in their academic career. In her interview, Alara stated:

Usually there is no publication requirement when you pursue a master's degree.

Generally speaking, Nergiz and I expect the masters students to have at least one publication. I remember two exceptions that masters students left the center and started to work in the industry. Students learn much more when they begin writing a paper for publication. We do invaluable work here. Publication is a means for them to pursue a post degree in a foreign country. (Interview August 10, 2010: translated by the researcher)

Qualities of Doing Scientific-Engineering Practices

The interdisciplinary learning and research was dependent upon the qualities of doing scientific-engineering practices. Faculty members associated qualities of their work with novelty, collaboration, and work ethics. In the center, novelty was aimed at contributing to the literature. Novelty would be accomplished by creating authentic research questions, generating techniques or methods, getting familiar with the relevant literature, gaining competence to write algorithmic functions, utilizing analytical and spatial thinking skills, and designing models and visual artifacts consistent with their research question. Thus, the novelty was to contribute to knowledge generation process through practicing, generating, and interpreting computer-supported modeling and

visualization of protein structures as illustrated in Figure 2 and Figure 3 rather than regenerating repetitive data throughout their research. Producing similar kinds of data that other researchers obtained would not be valuable to the community of computational biology.

As mentioned above, creating an original research question primarily determined the originality of their research. The original research question pointing to the gap in the literature and an unknown in the field emerged from the interactions and discussions between the faculty members and collaborators during meetings (including conferences and personal meetings). Then the faculty members shared the potential research question with masters and doctoral students in the research groups. Since both faculty members were not the center of action, the students carried out their investigation until they found something to contribute to the literature. Thus, seeking the novelty encouraged them to perform doing good scientific-engineering practices.

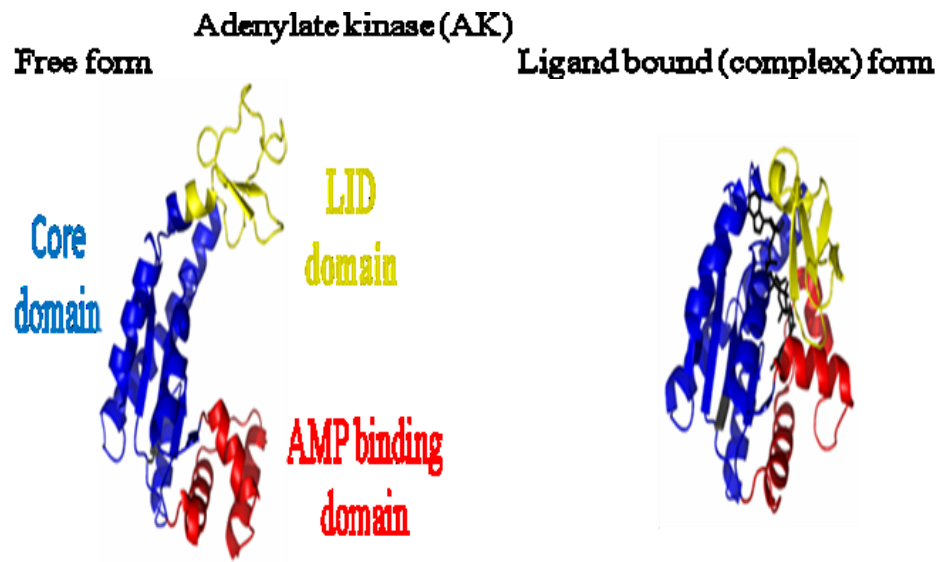


FIGURE 2 Closing motion of adenylate kinase.

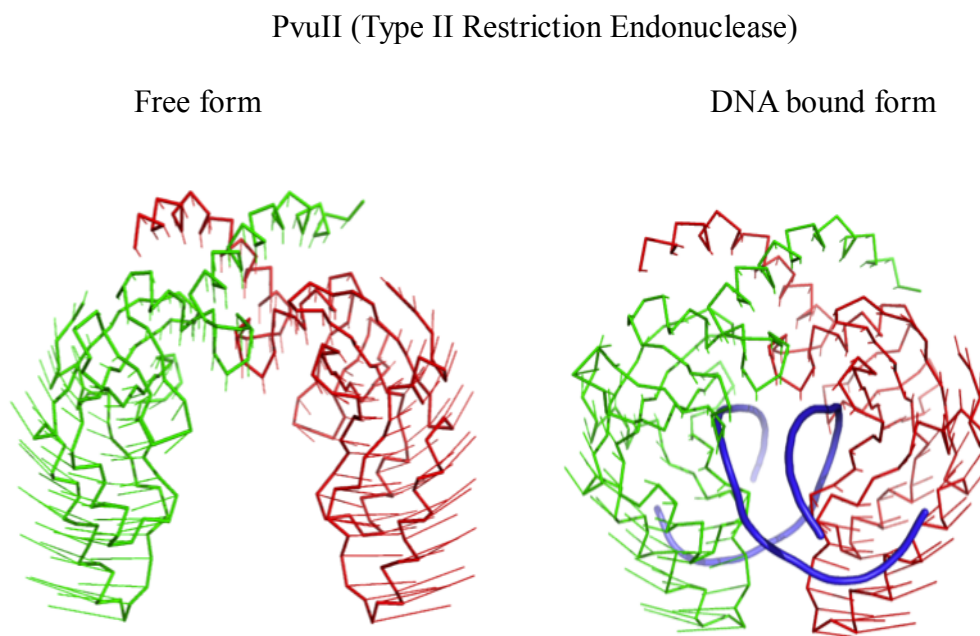


FIGURE 3 Opening/closing motion of type II restriction endonuclease.

Establishing collaboration with insiders (e.g., the center members and national allies) and outsiders (e.g., international collaborators) played a meaningful role in the quality scientific-engineering practice. The center members were all engineering researchers, but they were too far away from the conventional engineering practices, for instance, designing reactors. Instead, they were interested in understanding complex biological systems computationally. Their background allowed them to employ their analytical thinking, problem solving and spatial skills, and design capabilities. Nevertheless, the interdisciplinary aspect of computational biology required them to cooperate with researchers who have physics, mathematics, computer science, electrical engineering, and biology expertise and a variety of skills, techniques, and methodologies in the pursuit of unknown. They wanted to collaborate with them regardless of whether they perform their activities experimentally or computationally. They believed that computational biology studies were harmonizing with experimental biology studies. Collaborating with experimental biologists would accelerate and support their research. Incorporating different specially designed technologies, methodologies, and expertise into their practice would help them increase the novelty. Thus, initiating collaboration with a variety of researchers was a social mechanism for doing good scientific-engineering practice that was valued by the community of engineering researchers.

There were other potential characteristics that led the faculty members to perpetuate collaboration with other researchers. These characteristics were motivation, passion, capability, creativity, systematic work, awareness of innovations and developments in the field, and networking. The underlying reason for their collaboration

was that it was not possible for a researcher to have all personal, social, and cultural characteristics. The faculty members were cognizant of this circumstance and preferred working with a variety of researchers. Having collaborators with some of these characteristics would allow them to accomplish their mutual goal and support the originality in their contextual practices

The dynamic, collaborative nature of the research center encouraged the faculty members and the graduate students to develop a work ethic in their writing practices. On one hand, two core faculty members were always in contact with each other in their writing practices. Sometimes, they co-authored on their research papers as long as they conducted their investigation collaboratively. Other times, they helped each other by providing feedback and suggestions without co-authoring. Their established close friendship was the key to determining their collaboration in writing research papers and maintaining the habit of this work ethic. In her interview, Nergiz stated:

For instance, I include Alara's name as co-author, and so she does because we really work together and seriously contribute to each other's paper... Thus, we discuss our findings, results, and methods or techniques in our paper. We are so close friends, but we do not include our names as co-authors if we do not really work together. Yet, we acknowledge each other because of the feedback or comments. (Interview July 7, 2010: translated by the researcher).

On the other hand, the relations among the graduate students resulted in a different perception of work ethic to collaborate on writing research papers especially in Alara's group. Because mentors (e.g., doctoral students) always were in contact with

mentees (e.g., masters students) and engaged in mentees' projects, they were indirectly included in mentees' research papers. However, it did not mean that mentors helped them because they wanted to be co-authoring on their papers. Co-authoring between mentors and mentees was the consequence of their collaboration. Masters students conceived of themselves as a member of a family and/or a community. They believed in the solidarity among the members regardless of whether they were in the same research group. They always helped their peer in doing engineering investigations without coauthoring on their papers. Although they came to the center from different institutions, they took the same courses and became the members of the ongoing projects. Over time they established close friendship outside the center.

The Emergence of a Community of Practice

The research center depicted the characteristics of a community of practice because the researchers engaged in a joint activity that evolved over time, actively communicated with one another, mutually shared knowledge, practice, and experience with other researchers. The faculty members contributed to configuration of the different research groups, built and sustained communication structures, initiated mentoring process, and established multimembership across communities. The process of enculturation or cultural transformation was established through mentoring. Each member developed different roles and identities over time. Old-timers had a history in the group where newcomers gradually developed their own history. For instance, Nergiz and Alara have been working at the center for more than ten years. When the former director moved to the different laboratory in US, Nergiz took the lead to run the center.

Since then Alara has been the vice-director and Nergiz has been the director. The former researchers moved to the other institutions in order to work as faculty member.

Meantime, many graduate students joined the research groups and some of them left the group to work in the industry. Yet, Nur and Ozlem stayed to pursue doctoral degrees.

During the course of my observations, several master students joined the research groups at the center. Some began working with Nergiz. Some joined Alara's research group and worked with Ozlem and other group members. The center members generated and used methods or techniques to perform their contextual practice. Thus, the research center was a community of practice because the members developed relations and roles, shared mutual goals, participated legitimately in engineering practices, and maintained their membership to the community.

More specifically, in the center the members sustained their communication and interaction with each other through meetings. They organized formal (weekly and unscheduled) and informal (e.g., lunch and coffee breaks) meetings within the research team and with other groups. These meetings were the social platform where the center members usually discussed their problems, had disagreements and conflicts, negotiated their ideas, and provided each other with feedback and suggestions in order to continue their investigation. These meetings were a vehicle to make decisions together for the next week's plan and sustain their membership in the research group. These meetings motivated them to negotiate their weekly issues or concerns through mutual engagements rather than transferring knowledge from more experienced members (e.g., old-timers) to less experienced members (e.g., newcomers). Thus, these meetings

provided each member with benefits that they learned from each other. In her interview, Ozlem stated:

Let's say four people are having a meeting... different, interesting questions that other three people ask contribute to project's progress...everybody has different perspectives indeed...they look at a problem from different windows and we learn to look at it from all different perspectives...at the same time, my position changes because I can see different perspectives from a different angle and evaluate my position. (Interview June 28, 2010; translated by the researcher)

A masters student, Mert, leading a project under supervision of his mentor (Ozlem) and advisor (Alara) said that weekly meetings were meaningful and supportive. He could regulate his learning and research because interaction and communication with the faculty member and the doctoral student helped him build on his understanding and knowledge. In his interview, he stated:

Weekly meetings are useful... at least what happens...process goes faster. Every week, you build on previous week's work...encounter different things... We share our ideas with each other. Faculty members interpret things within their knowledge and experience. Ozlem says something...I say something...I think that everyone benefits from this ...I think that the faculty members benefit from it as well. I benefit more from what they say...the faculty members say something that you haven't known. This is a shortcoming. Therefore, you feel you have to know it or search for it somehow. (Interview August 2, 2010; translated by the researcher)

Weekly meetings provided the masters students with the opportunity to show their performance and support learning progression. They were assigned to do their weekly assignments. Each week their advisor and/or mentors gathered to review and evaluate the masters students' assignments. Throughout the meetings, they discussed the assignments' findings and results with each other. The masters students received constructive and supportive feedback and recommendations to accomplish their task. They benefited from their mentors' experience as well as innovative strategies that emerged in the weekly meeting to solve their engineering problems or tasks. Thus, their participation in the meetings essentially was important to sustain their learning and research, and contributed to developing their individual researcher roles.

Research members were expected to attend the weekly meetings. Participating in the meetings became a social norm over time. This norm was a means for them to maintain their membership within a research group. Each member had different forms of knowledge, competence, and experience, but they respected and trusted each other. They utilized this diversity to accommodate their disagreements, conflicts, and problems through mutual negotiations. Since more experienced members were aware that the masters students needed to learn the specific content and methods in order to accomplish their task, the masters students were encouraged to make necessary changes or modifications associated with their weekly assignments. The diversity of expertise, competence, and experience in the research group increased their engagement in the meetings and strengthened their sense of belongingness to the group.

Informal meetings were considered as ways to access individuals and encourage reciprocal learning. Informal meetings during lunch and coffee breaks were among the social activities that the center members engaged in, socialized, and communicated with. Although they worked on the different projects and used different methods to solve their task, they built connections with one another naturally. Usually, members in the same research group developed a closer relationship with each other. Yet, they also tended to have meetings with the other groups' members because they conceived of themselves as a member of the center and always had something to talk and discuss regardless of expertise, experience, education level, and research group affiliation. These meetings were a social route to learning from each other and checking their understanding, capability, and works. Their mutual negotiations helped them to review, revise, and reconstruct their investigations. Thus, informal meetings where members shared their experience, knowledge, and different, innovative feasible ideas with one another were a means to sustain their research and enhance their learning and development. In her interview, Nur stated:

For example, we are having lunch. While you are talking about your research, one person comes to you with an idea...while you are talking about something, another person evaluates your idea and disagrees with you...when this happens, you revise your idea or seek out what she said or you think you are right.

(Interview July 9, 2010; translated by the researcher)

Newcomers (e.g., masters students) in the center were immersed in the process of enculturation in a community of practice. To achieve their cultural transformation,

mentorship emerged naturally and temporally. Mentorship was viewed as a way to help newcomers recognize knowledge, a shared practice, skills, a set of resources, and strategies that the community members produced and used to perform their daily research practices. Nevertheless, mentorship grounding the enculturation process was a tacit norm that contributed to a community of practice in the center. Mentorship was implemented by doctoral students. They established the interaction with the newcomers. Their interactions with the newcomers aimed at helping them obtain technical knowledge and practical knowledge. With guidance from the doctoral students, the newcomers were able to adopt the norms of the center, and gain design and critical thinking skills to generate computational models and use visualization techniques. Then, the newcomers would make progress on the trajectory of becoming an engineering researcher/practitioner in the center and move from periphery to center in a community of practice.

The research center has gained its reputation with the methods or the techniques that former and current faculty members have generated. Since the research groups in the center performed their practices through computational modeling and simulations, they needed to create their own techniques instead of using the ready-made software techniques. They would then use them within the research groups and share them with other researchers. For instance, they wanted to use molecular dynamic simulation as a technique to understand the protein structure at the atomistic level. When they investigated the protein structure in less detail, they obtained very fast and efficient simulation. In turn, they missed the atomistic details of protein structure. They preferred

generating their own techniques to investigate the protein structures in more or less details because the ready-made software techniques as friendly tools were fixed and stable, and there was no chance to modify and redesign the protein structure in light of their research question. Therefore, generating their own techniques or methods was the key to accomplishing their goal. In addition, their own techniques were a means for them to contribute to the originality and augment the quality of their practices. This aspect allowed the research center to sustain its reputation that impacts engineering researchers' performance and productivity in communities of practice (Cole & Cole, 1973).

The research groups generated and used a shared repertoire (e.g., supercomputer products, visualization tools, and simulation techniques) to create and predict the dynamics of protein samples. The protein dynamics were considered as the evidence to explain how and why a particular protein behaves and interacts with one another in any given circumstances. Research group members used a supercomputer to run computational simulations and generate artifacts (e.g., 3-D protein structures) to understand biological complex systems. Without the supercomputer, the center would not exist. Since the supercomputer was the experimental tool that accelerates the implementation of molecular dynamics and Monte Carlo simulations, and that helps them to generate artifacts, the faculty members needed to renew and strengthen its capacity. There were two reasons to do so. First was that they needed to efficiently visualize protein folding dynamics. Second, the recent scientific-engineering studies and ever changing expectations in the community of engineering scientists urge them to use higher capacity of server to obtain high quality artifacts. Low quality and poor visibility

would not contribute to the knowledge generating practices. Therefore, the quality and visibility of protein structures depended on the functionality of the supercomputer. The products of supercomputer runs were shared in the research groups. Group members discussed whether the products could be used as data to support their research question. Visualization tools were to identify anomalies in protein structures and were a means to determine the use of the protein structures obtained in their reports. The products generated by the supercomputer were the part of a shared repertoire of the community that helped engineering researchers to continue their investigations

Discussion

In this study I investigated how novice practitioners develop expertise, personal identities, and researcher roles in the scientific-engineering community. The research center studied did not resemble research laboratories as physical space as in other ethnographic studies (e.g., Latour & Woolgar, 1986; Traweek, 1988), but it was an organizational system that had the cognitive, material, and socio-cultural dimensions of human activity. These dimensions were not mutually exclusive; instead, they were complementary with each other. Herein, I present and discuss the dimensions of the scientific-engineering practice in the research center.

First, the cognitive account of the scientific-engineering practice referred to the familiarity with the theoretical background, PDB (consists of protein structures experimentally obtained from crystallography) and knowledge to perform algorithmic programming, generate, and interpret theoretical and computational models, and simulations via different approaches (e.g., molecular dynamics and Monte Carlo). The

theoretical background associated with the content-specific knowledge grounded the research hypotheses and allowed the researchers to predict about the protein folding dynamics. Engineering researchers at the center used algorithmic programming and visualization tools to reconstruct and better understand protein structures. These techniques were essential in designing three- dimensional computational models of protein structures. However, this process required the researchers to use their spatial and analytic thinking skills as well as to develop adaptive expertise.

Protein structures were predictive in nature because they emerged from experimentally developed ones through algorithmic programming. The predictive structures were viewed as approximations of experimentally developed protein structures. That is to say, computational models of protein are generated as approximations to specific circumstances (Miller & Page, 2007). Engineering researchers used and regenerated these structures for new tasks to make further predictions. For example, they might assume that protein structures were mutated or deformed by a virus or a disease. Such a prediction was then considered as a way or a solution that either facilitated experimental studies or contributed to a specific drug design for the deformation of the amino acid sequence. In this sense, algorithmic programming helped engineering researchers construct and manipulate computational models of a particular protein conformation and simulations with defined coordinates in space. By doing so, they created predictive protein models. All of this addressed the computational model-based reasoning. In the reasoning process engineering researchers focused on discovering observed phenomena, but revising and improving them with

unobserved variables and processes (Langley & Shrager, 2002) and created new things from existing objects and phenomena (Lazaro & Marcos, 2005). The computational aspect of scientific practice in engineering reflected “the physical world in the virtual world of computer networks” (Crnkovic, 2010, p. 363) through cognitive artifacts (e.g., computational models and simulations) (Nersessian, 2009). Thus, the cognitive dimension of scientific-engineering practice encompassed computational reasoning processes depending upon algorithmic programming, modeling, visualization, and simulation skills.

Second, the material dimension (e.g., instruments and devices) in performing scientific practice has gained prominence in communities of science and engineering. Pickering (1995) pointed to the mutual relationship between human and non-human agents in scientific practice. As Traweek (1988) noted, the material agents were essential to the ontological dimension of the particle physics community. In this case, the members of the scientific-engineering community designed, revised, and experimented with *in vitro* computational models and simulations; generated techniques, tools and methods; and upgraded their experimentation tool (supercomputer) in order to continue to generate representations of the real world. Models and simulations were epistemic activity tools in their engineering practice (Boon & Knuuttila, 2009; Nersessian & Patton, 2009). In addition, these tools as non-human agents permitted the center members to predict and explain the behavior of proteins. Hence, the material dimension of the center included the models and simulations that helped them continue to do their contextual practices.

Computational models and simulations were socially constructed theoretical notations, mathematical concepts, and algorithmic techniques in the field. The fruits of these models and simulations were a deeper understanding of protein complex systems and scientific explanations that help develop a better foundation for important decisions to perpetuate their engineering practice. In other words, computational models and simulations were dynamic, complex, cognitive representations of reality that the research center members used to describe, explain, and predict complex protein folding structures. Thus, the research center members designed, revised, and utilized these socially constructed artifacts to investigate real-world phenomena within the material context of scientific-engineering practice.

Third, the socio-cultural dimension displayed the interdisciplinary learning and research, and the enculturation process grounded by mentorship. The interdisciplinary learning and research referred to the involvement of several fields of study including mathematics, physics, biology, and engineering. That is, the partnership among these disciplines was a way to convey the pedagogical and research perspectives to the graduate students (both masters and doctoral students) as well as to the faculty members. The interdisciplinary learning and research at the center was sustained by an intellectual process and a sense of belonging to the research group (Wenger et al., 2002). Regardless of the faculty working styles, the graduate students were the leaders in projects under their mentors' supervision. Ongoing communication through formal and informal meetings facilitated graduate students' learning and development processes. These meetings as the components of the interdisciplinary learning and research processes

primarily provided the research group members with the opportunity to discuss their routine works and findings related to ongoing research as well as to share their knowledge, experience, and ideas, and generate feasible ideas to solve their problems. During the meetings they encountered both agreements and disagreements or conflicts that were part of the social participation features establishing a shared practice among the research group members (Lave & Wenger, 1991; Wenger, 1998).

Mentoring relations were a means for maintaining the process of enculturation. Mentoring was described slightly different in the literature (Abell, Dillon, Hopkins, McNerney, & O'Brien, 1995; Anderson & Shannon, 1988; Franke & Dahlgren, 1996; Guberman, Saks, Shapiro, & Torchia, 2006; Johnson, 2003; Koballa & Bradbury, 2009; Wang & Odell, 2007). Guberman et al. (2006) viewed mentors as advisors, supporters, tutors, masters, sponsors, and models of identity. Mentors were described as counselors, coaches, advocates, and friends (Anderson & Shannon, 1988; Johnson, 2003). Mentors were considered a source of practical knowledge and personal/moral support (Melville & Bartley, 2010; Thiry & Laursen, 2011). In addition to these roles, at the center, the analyses revealed that the mentors were mediators between newcomers and the faculty. The mentors with whom I interviewed considered themselves as tutors. They helped newcomers acquire the cultural knowledge in the research groups and norms, values, and practices within the community (Thiry & Laursen, 2011; Wenger, 1998).

The mentoring process provided opportunities for both mentors and mentees. For mentors, the mentoring was a social route to becoming a scientific-engineering researcher and faculty member. For mentees, mutual interactions and negotiations with

mentors supported them to socialize in the profession and receive personal and intellectual support (Guberman et al., 2006). For both mentors and mentees, the mentoring process provided a trajectory of identities towards being full participants in the community of practice, and it was a means to enhance cultural transformation (Hunter et al., 2007; Lave & Wenger, 1991).

Overall, the center members' activity had the cognitive, material, and socio-cultural dimensions to better understand natural phenomena in the virtual world. The success of their work in the center depended not only on how well they performed their contextual practices, but also on how well they recruited newcomers and how well they sustained their collaborative partnership to continue engineering research and cultivate engineering researchers.

Implications for STEM Learning Environment Design

This study explored the distinct characteristics of the scientific-engineering community and investigated how the community members sustained learning and research through interaction and communication, how they operationalized their contextual practices, and how novice members became scientific-engineering practitioners throughout their participation in the community. These findings have potentially insightful implications for STEM learning environment design. They explain the characteristics of the community members' ongoing communication and collaboration that allow the members to seek novelty in their practice. They also address how a mutual agreement is emerged in a group of researchers about the relationships

between the material and the sociocultural aspects of scientific practice as human activity.

When STEM educators (both pre-service and in-service teachers) are involved in interdisciplinary learning and research environments, they can witness how research groups are socially evolving, how the members perform authentic tasks, and how they seek to answer an unknown question both individually and collectively. In other words, they can experience that interdisciplinary scientific-engineering community has both social and cognitive processes of human activity (Paletz & Schunn, 2010). As mentioned in the findings section, the research groups were formed by the faculty's working styles at the center. STEM teachers can model the distributed research group that included individuals at different levels of expertise and competence with different interest of study. In the distributed research group, the graduate students were the center of action and performed engineering tasks under the auspices of their mentors through mutually interacting with each other. In classroom communities, heterogeneous research groups can be socially constructed by students and the teacher in light of their interest, knowledge level, and ability. Assuming that each student is at different knowledge levels, more knowledgeable and skillful students can be selected and encouraged to be mentors. Mentor students can help their group members attain knowledge and gain the ability to perform their contextual practice through mutual negotiations. They can be the representatives of their research group and contact their teacher directly. Yet, mentoring should be transformative. In other words, different individuals with different expertise and competence in a group can take the lead and manage their daily activities over time.

Thus, this transformation can handle potential power relationships among group members. It is important to note that when participants have varied experience, competence, and knowledge in the group, mentoring occurs naturally. Having a homogenous student population in a class is very likely to avoid the occurrence of the mentorship.

Observations in this study indicated that regardless of the faculty's working style and communication structures in the center; the research groups were in the pursuit of unknown. Generating a research question was the determinant of the quality research or the novelty. Their research question emerged from the faculty's interactions, collaborations, and communications within the community and with the other research communities over meetings. The faculty members had developed broker roles in addition to their researcher roles. They encouraged the graduate students to be responsible for generating hypothetical solutions to the research question given by the faculty members. They pursued an unknown instead of something already known by their professors or in textbooks. In classroom communities, STEM teachers can play similar broker roles that can establish the partnership between education and STEM communities. This partnership can allow teachers to realize and share novel and interesting topics with their students. Teachers can provide research groups with an original research question to answer. Seeking an answer for that question can also motivate students to take the ownership of their investigations and learning, work with others outside the boundary of their classroom community, and pursue science and engineering as their future careers.

This study sheds light on the importance of the material dimension of scientific-engineering practice. The community at the center performed computational activities in engineering design. Engineering design required the community members to use interdisciplinary knowledge and design skills to generate a solution to their engineering problem in computational biology. Engineering design process was iterative. Engineering researchers developed and tested a theory related to their research problem. That process included the creation of new methods or techniques to accomplish their task. In classroom communities, students can be engaged with a research problem and motivated to generate their ideas to solve that problem. Throughout the process, they can be allowed to create and test theories and methods in a way that helps students gain design, computational thinking, systems thinking, and analytic thinking skills. However, a semester long project will not be sufficient to perform iterative design. Typical semester long class meetings are likely to eliminate the potential of iterative design activities because the center members have been involved in multiple-year long projects as I observed their activities over two months.

Furthermore, the community members constructed, modified, and redesigned computational models and simulations in the interdisciplinary context of computational biology. In the problem solving process, computational models and simulations were primarily the ways to solve biological engineering problems. In classroom communities, students can generate their computer-based models and simulations in order to solve problems. They can develop models through a series of develop-test-revise cycles. Yet, the computational models and simulations the center community members generated

were complicated and advanced. They were to great extent epistemic activities. In high school classroom communities, students can be encouraged to gain basic mathematical and computational thinking skills and learn computer-programming language via the ready-made software programs appropriate for their understanding and conceptualization. They can describe and understand the natural phenomena or processes (e.g., protein dynamics or atmospheric dynamics), which may not be accessible with direct observation and experimentation in the real world. Thus, computational models and simulations can be used as educational and epistemic tools to investigate real world topics relevant to science, technology, engineering, and mathematics and expand their knowledge and understanding (Louca, Zacharia, & Constantinou, 2011; Smetana, & Bell, in press).

Establishing and sustaining communities of practice in educational settings can be considered as another implication of this study for STEM learning environment design. Students can be encouraged to get involved in authentic tasks and generate ideas through mutual communications and interactions. They can be asked to generate tools, methods or techniques. These constitute a shared repertoire the community members use to accomplish their evolving joint enterprise. Building a community of practice also means building an epistemic community where its members utilize their knowledge and competence to generate new knowledge.

Concluding Remarks

This study represented and discussed the characteristics of the scientific-engineering community within the cognitive, material, and socio-cultural contexts. It draws on etic and emic perspectives in order to portray the characteristics of the community whose members had different roles and responsibilities to maintain learning and research practices. The ethnographic eyes allowed me to highlight the nature of doing scientific-engineering practices and capture the passion that each member had to accomplish their authentic and complex tasks. Participant observations allowed me to identify the interdisciplinary aspect of the research center and the solidarity in the community. In the synergic learning and research environment, the center members respected and trusted their expertise and competence as they performed their contextual practices.

This research suggests that further ethnographic studies in similar settings will serve to portray a richer understanding of scientific-engineering communities. These studies will elicit the features of other multidisciplinary communities and expand scientific methodologies, technologies, and applications to understand natural phenomena. By doing so, STEM education researchers and learning scientists will be better able to design knowledge-building communities where STEM students can carry out STEM-related practices and conceptualize the interrelationships between science, technology, engineering, and mathematics.

CHAPTER IV
EXPLORING SOCIAL DYNAMICS IN SCHOOL SCIENCE CONTEXT:
AN ETHNOGRAPHIC STUDY

Overview

The goals of this study are to delineate the socio-cultural aspects of learning in a science classroom and investigate the social practices and participants' interactions that establish and maintain participation, community, and meaning, with a purpose to inform the learning environment design efforts in school science context through detailed depictions and analysis. I sketch two vignettes to reflect the social nature of the science classroom in terms of participation, practice, meaning, and community. I identify normative practices and routine behaviors emerged in a science classroom, material and discourse resources, and differential modes of participation accompanied with different roles and responsibilities. I discuss the potential barriers and opportunities that impact the emergence or absence of a community of practice in the classroom. My discussion of practices students engaged in includes participation modes, social relationships established among the students and the teacher, and the teachers' authority over learning activities and student revelations of how learning science occurs. These sources help me understand why a community of practice is not evolving. I suggest science education researchers consider the aspects of the classroom within a community of practice context to help develop a new participant structure that acknowledges complexity in the social learning system of a classroom.

Introduction

Sociocultural approaches examine classrooms as complex adaptive systems (Logan & Schumann, 2005; Burns & Knox, 2011) and provide a deeper understanding of social and cultural systems of classrooms (Kozulin, Gindis, Ageyev, & Miller, 2003). Teachers and students develop, use, and share knowledge to engage in their contextual practices, and they learn from each other through interactions and collaborations (Watson & Battistich, 2006). A classroom culture including participants' roles, their relationships with one and another, and participant identities characterizes the group membership (Barab & Duffy, 2000; Collins, 2006; Lave & Wenger, 1991; Wenger, 1998). Members of classrooms are socially engaged in constructing their norms and rules through daily activities that develop social relationships and sustain mutual engagement (Hogan & Corey, 2001; Gallego, Cole, & The Laboratory of Human Cognition, 2001). It is through these shared norms that members of one classroom community can build connections with those of other classroom communities (Wenger, 1998). Yet, classrooms as social contexts are more likely to be configured and reconfigured by the social authority and epistemic roles of the teachers (Berland & Hammer, 2012). Teachers can be defined and perceived as the primary actors responsible for organizing and managing normative classroom practices, and in establishing interactions (Bauchspies, 2005).

Ethnographic studies of science classrooms provide a lens for understanding the socio-cultural aspects of classroom communities. These studies underline scientific identities developed over time (Aschbacher, Li, & Roth, 2010; Olitsky, Flohr, Gardner,

& Billups, 2010; Smithenry & Gallagher-Bolos, 2010) and examine the elements of a community of practice that emerged in school settings (e.g., Aguilar, 2009; Enyedy & Goldberg, 2004; Olitsky, 2007; Shanahan & Nieswandt, 2011). In the present study I explored and documented the daily activities of students and their teacher, and described the social structure of a science classroom in order to identify social dynamics that support or hinder the emergence of a community of practice in school context.

Research on students' learning has shifted in focus from understanding students' individual cognitive learning processes to exploring their collective, social learning processes that underscore participation, collaboration, and identity (Nasir & Cooks, 2009; Wenger, 1998). This shift allows us to see learning not only as a cognitive process but as a sociocultural process as well (Aguilar & Krasny, 2011; Gutierrez & Rogoff, 2003). From this perspective, students' learning science is considered within the socio-cultural and cognitive contexts as they are engaged in a shared practice in school science classroom community. In short, learning science should occur within communities of practice (Wenger, 1998). In this study, I explore the characteristics of a community of students by (a) addressing their social practice, their interaction and communication, and their norms and behaviors; and (b) exploring the barriers or the opportunities for a community of practice to emerge in a science classroom.

Many researchers examined the community of practice notion in educational research (e.g., Aguilar, 2009; Olitsky, 2007; Roth, McGinn, Woszczyna, & Boutonne, 1999). Aguilar (2009) identified students' learning in school science context by addressing the three interrelated constructs: (a) mutual engagement, (b) joint enterprise,

and (c) shared repertoire. She conceived of knowledge transmission by the teacher and non-participations of the students as a barrier to the development of a classroom community of practice. Olitsky (2007) found that different types of interactional events (e.g., one-on-one and whole-class) are a means to increase student engagement and student learning as well as to form a classroom community of practice. In contrast, Roth et al. (1999) found that a small number of students participated in science classroom discourse practices although students were provided with the opportunity to develop their own artifacts through different levels of social configuration (e.g., whole-class and small group). Yet, little research has explored the social dynamics that trigger or hinder the emergence of a community of practice in school context.

The primary goals of this study are to explore the socio-cultural aspects of learning science in a science classroom and investigate the social practices and participants' interactions. Another goal is to identify the social dynamics that connote emergence of a community of practice in school context. For these purposes, an ethnographic study was conducted in a science classroom. The class was chosen using the convenience sampling strategy because of its accessibility and proximity to the researcher. I contacted two teachers to get permission to attend their class sessions. I talked to them about my research and its purpose. One of the teachers was a new teacher in school and her schedule was very busy. She rejected my request. The other teacher I contacted was more experienced. I had helped her students for a science fair at the weekends prior to my research. She accepted my request to conduct the study in her classroom.

Research questions are stated as:

- (1) What is the nature of the ‘participant structures’ (barriers and opportunities) emerged within the cultural events the students participated?
- (2) What dimensions of the communities of practice emerge within these events?
- (3) What is the nature of the students’ science practices?

In the theoretical framework section, I discuss the social structure of school science classroom and the communities of practice notion. In the methods section, I describe the classroom setting and my involvement in another culture. Next, I present the analysis of two vignettes to show the classroom community members’ engagement in two different cultural events and their roles and responsibilities. Following is the findings addressing the social organization of the classroom community and the contextual practices its members performed. Based on my findings, I discuss the social dynamics (e.g., barriers or opportunities) that trigger or hinder the formation of a classroom community of practice. The study findings inform the efforts to design and build a dynamic and collaborative classroom community that conveys learning as participation, belonging, and practice, and that transforms students’ identities over time.

Theoretical Framework

School Science Classroom Community and its Social Structure

In most science classrooms, individuals develop common knowledge through negotiating and sharing their understanding and experience, and collaborating with each

other (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Elbers, & Streefland, 2000). Sometimes they encounter conflicts with and resistance to their ideas, thoughts, and claims emerging from their mutual engagements throughout the learning process (Olitsky et al., 2010; Oliveira & Sadler, 2008). These temporally emergent circumstances are accommodated through the social interactions and negotiations among the classroom members (Mortimer & Scott, 2003; Roychoudhury & Roth, 1996). The focus of this study is these social interactions and negotiations (Lave & Wenger, 1991; Wenger, 1998), because they lead to a shared repertoire among the members and help develop individual roles and identities (Aschbacher et al., 2010; Olitsky et al., 2010). The social participation characteristics including conflicts, tensions, and disagreements are central to form and sustain a classroom community of practice and are central to this study for understanding the emergence or absence of a community of practice within a science classroom.

Philips (1972) coined the term ‘participant structures’ as the context of participants’ engagement, their social norms, relationships, roles, and responsibilities, and the materials and knowledge acquisition. One can analyze and articulate the social structure of a science classroom using ‘participant structures’ (Cobb, Stephan, McClain, & Gravemeijer, 2001; Cornelius & Herrenkohl, 2004; Greeno, 2006; Shepardson & Britsch, 2006; Smithenry & Gallagher-Bolos, 2010). The ‘participant structures’ explain “the distribution of the functional aspects of the activity, including agency, authority, accountability, leading, following, initiating, attending, accepting, questioning or challenging, and so on” (Greeno, 2006, p. 82). They illustrate how class members

participate in and sustain their practices, what roles the teacher and the students are engaged in, what relationships they establish in maintaining memberships and what types of resources are shared and generated (Cornelius & Herrenkohl, 2004; Herrenkohl & Guerra, 1998; Tabak & Baumgartner, 2004; Smithenry & Gallagher-Bolos, 2010). All of these define a community of practice within the school science classroom (Wenger, 1998).

The contextual practices that communities perform define the types of learning and knowing (Barab & Duffy, 2000; Collins, 2006). Practices engage individuals with the social world in order to develop, share, and maintain knowledge as well as actions that evolve over time (Berland, 2011; Enyedy & Goldberg, 2004). Yet, contextual practices that school science communities perform are different from contextual practices that professional science communities do (Shanahan & Nieswandt, 2011). Professional science communities perform their contextual practices to generate new knowledge, and scientists-in-the-making develop ideas, goals and plans to continue to do scientific practice. In most school science classroom communities, practices are organized to represent and reproduce scientific knowledge already known rather than to generate new understanding (Kirch, 2010). Moreover, scientific knowledge disconnected from real-world themes is transferred to students by the teacher through lecturing (Carlone, 2004; Carlone & Johnson, 2007). Students are often provided with structured hands-on activities, and these activities are rarely open-ended. These activities demonstrate the science textbooks' representation of scientific knowledge.

School science practices are viewed as the safe version of practices scientists perform in professional science communities (Archer et al., 2010). Activities offered to students are not similar to everyday activities of scientists in research laboratories (Chinn & Malhotra, 2002; Hofstein & Lunetta, 2004; Turner & Sullenger, 1999). These activities lack the authenticity of scientific practice and discourage students to learn from authentic tasks relevant to real-world problems (Höngström, Ottander, & Benckert, 2010). Authenticity refers to the social nature of scientific practice that encompasses commitment, uncertainty, peer review, and so on (Bricker & Bell, 2008; Edelson, 1998; Ford, 2008; Weinstein, 2008). Most school science classroom communities have students both learn and do ‘safe version of real science’ through the well-defined, structured activities based upon observation and experimentation that verify certain knowledge and represent science as a stable body of knowledge (Bencze & Hodson, 1998; Munby, Cunningham, & Lock, 2000; Rudolph, 2003). Thus, school science classroom communities are not developing a practice over time because teachers organize activities that students engage in according to curriculum objectives, standards, and standardized testing.

Social Learning Theory: Communities of Practice

Learning is a collective activity between the person and the social world rather than an individual activity in the mind of a learner (Kumpulainen & Renshaw, 2007; Wenger, 2010). Wenger (1998) views learning as ongoing social process in which individuals negotiate and transform identities over time. This learning process is

attributed to the notion “communities of practice” (Lave & Wenger, 1991; Wenger, 1998).

A community of practice is a collection of people engaging in a shared practice, working collectively on a common interest, and sharing a set of problems and a passion about a topic (Wenger, McDermott, & Snyder, 2002). It pertains to “the common tasks members engage in and the associated practices and resources, unquestioned background assumptions, common sense, and mundane reason they share” (Roth, 1998, p.10). Choi (2006) views a community of practice as “relations of people who have in common a shared competence and mutual interest in a given practice” (p.143). In addition, a community of practice is considered as a social learning system that exhibits many characteristics—emergent structure, complex relationships, self-organization, dynamic boundaries, and ongoing negotiation of identity and cultural meaning (Wenger, 2010).

Wenger (1998) delineates the features of communities of practice—practice, community, meaning, and identity. First, practice—learning as doing—refers to learning occurring through participating in a practice. Second, community—learning as belonging—is a space in which its participants negotiate enterprise with each other, do things together, and establish relationships with other participants (Wenger, 1998). Third, meaning—learning as experience—is that people experience the world through practice individually and communally. They make sense of the world as meaningful by establishing relationships, negotiating their experience, and participating in an activity. Fourth, identity—learning as becoming—explains how learning changes peoples’ role when they participate in a practice (Wenger, 1998). Within communities learning is an

intellectual competence, a connection between “the head as well as the heart” (Wenger et al., 2002, p. 29).

A community of practice encompasses three indicators—mutual engagement, joint enterprise, and shared repertoire (Wenger, 1998). Mutual engagement is attributed to membership, diversity, and relationship within a community that creates a joint enterprise among the members. “The enterprise is the result of a collective process of negotiation that reflects the complexity of mutual engagement. It is not just a stated goal, but creates among participants relations of mutual accountability that become an integral part of the practice” (Wenger, 1998, pp.77-78). This in turn creates a shared repertoire as a set of resources including routines, ways of doing things, words, tools, actions, concepts or discourse that the community members use and/or produce to sustain their memberships in a community.

Central to a community of practice are participation and identity transformation (Wenger, 1998). Participation is a catalyst to developing and sustaining a community of practice in a way that shapes members’ actions and identities. Participation is not limited to engaging in activities; it also is a process of becoming a full participant. In this sense, it is suggested that students be encouraged to engage in authentic tasks in a community of classroom practice in which a novice learner or a newcomer adopts and uses a classroom community’s norms and beliefs to become a full member of that community (Roth, 1998) as opposed to grades and exams emphasized in most conventional classrooms (Barab & Duffy, 2000). Identity transformation occurs in the context of becoming a full member in a community. Individuals at different levels of participation

and membership become familiar with and use knowledge, and master skills of a community through their personal trajectories of participation (Clark, 2005; Wenger, 1998). In the classroom context a student learns as she develops and transforms her identity through her personal trajectories of participation in a shared school science practice.

Researchers have been interested in developing a community of practice in educational settings (Christiansen, 2010; Clark, 2005; Goos, Galbraith, & Renshaw, 1999; McLaughlin & Talbert, 2006). They examine the elements of communities of practice and use communities of practice as a framework to understand how individuals learn (Aguilar, 2009; Aguilar & Krasny, 2011; Boylan, 2010; Enyedy & Goldberg, 2004; Olitsky, 2007; Shanahan & Nieswandt, 2011). Yet, there are only a few studies that explore and document the potential dynamics that determine whether or not a community of practice emerges within school settings, and how it does/does not emerge (Aguilar, 2009; Olitsky, 2007; Olitsky et al., 2010; Roth et al., 1999). In this study, I contribute to this work with a study of learning and teaching science in a seventh grade science classroom by highlighting the authenticity of normative school science practices, interactional patterns among members of the classroom, power relations, and the cultural portrait of the classroom. In order to address these issues and to move beyond the earlier studies, I will draw attention to barriers and opportunities within the classroom that reflect the social nature of the science classroom community and examine the elements of the classroom's community of practice.

Methods

The Setting

This ethnographic study was conducted in a classroom at a charter school run by a non-profit educational organization that operates 33 campuses in the state of Texas in the U.S. The charter school has a shared mission that students learn the physical sciences and mathematics in a collaborative learning atmosphere using computer application. Students are encouraged to participate in supplementary after-school programs (e.g., science fair, science and mathematics Olympiads) under the auspices of their teachers and outsiders (e.g., graduate students and university faculty members).

The charter school hosts approximately two hundred fifty students in kindergarten through 12th grade in the same building. With one class for each grade level, it is one of the smaller schools in the Public Schools system. The seventh-grade classroom, which is the focus of this study, had twenty-two students at the age of 13-14. Of twenty-two students (seven male and fifteen female), approximately, eighteen percent were African-American, thirty-six percent were Hispanic American, and forty-six percent were White.

Ms. Corbin was the certified physical science teacher who has been teaching seventh and eighth grade science courses in the middle school and physics, biology, and chemistry courses in the high school over ten years. She has been organizing and supervising in- and out-school activities relevant to physical sciences for the last three years. During my research, she used the science curriculum conforming to the state's science standards. She organized and implemented the classroom activities pertaining to

nature of science, biology, earth science, physics, and ecology. More specifically, she helped students conduct scientific investigations and gain scientific inquiry skills during laboratory activities. She taught four main, specific topics represented in the curriculum throughout the two semester: (a) matter and energy; (b) force, motion, and energy; (c) earth and space; and (d) organisms and environments.

In this study, names of students and the teacher have been changed in an effort to protect the confidentiality of the individuals at this school. Their names are all pseudonyms.

The Introduction to the Site

I made my first visit to the charter school in Fall 2008. My introduction to the school was as mentor to the fourth and fifth graders to help them prepare their science fair projects for the school competition. I worked with five students for seven weeks before the science fair every Saturday morning until noon. My voluntary assignment was to meet with students on weekends at the school to discuss and guide their project purpose, procedure, and results that would be displayed upon a poster that they designed. Students were expected to conduct their experiments at home and through the weekly meetings they would go over what they had found, what their results looked like, and how they would present their project. These meetings provided students with the opportunity to present and discuss their results. They talked to me about their project topic, the way they conducted their experiment, and whether they answered their research question, and problems they faced during experimentation. I provided them

with feedback and suggestions in order to complete their project as well as to support their readiness for the competition.

One year later, I was invited to serve as judge in the charter school's annual science fair. I was given fifteen projects randomly to evaluate. I was expected to evaluate four science projects at sixth grade level; three projects at the seventh grade level; and three chemistry projects at ninth grade level. I was also given three physics projects at tenth grade level and two biology projects at eleventh grade level. As a judge, I spent the entire day talking with students about their projects. I observed that some students were self-confident and talkative, while others were silent and reluctant to explain their project to me. For those who were silent, although they had well-prepared and colorful posters, they did not want to talk to me directly unless I asked questions. They just showed up in the science fair. However, other students participated at a very high level in ways that appeared to challenge themselves and their peers and reflected a high level of scientific engagement. They were ready and willing to explain their project and answer my possible questions. When I stopped by their poster, they started to talk to me about their project immediately. This high student engagement in the science fair appeared to symbolize their relationship to science, learning and the school, and triggered my questions about practice, community, participation, and meaning in learning science.

Research Activities

In Fall 2010, I returned to the same school as a researcher and a participant observer to conduct my observations of student engagement in a formalized manner. The

school's administration and Ms. Corbin granted me permission to observe the seventh grade science every week for two semesters. It took two and half months to obtain an IRB approval partly because my participants were minors. Then, I started to attend the class-sessions and observe student and teacher interactions, and school science practices.

Participant observation took place in the seventh grade science classroom throughout the academic year of school. It was selected as the main methodology in order to understand and explore their behaviors and actions during the classroom cultural activities (LeCompte & Schensul, 2010). I spent my time observing the class periods every week and writing daily journals. During laboratory activities, I joined two of the six groups in order to observe student communication and collaboration and to interact with them. I engaged in their group activity as a member. They asked me questions about the activity provided to them. They conducted their investigations and collected data with me together. During these interactions I asked them both rhetorical and literal questions in order to either understand what they think they are doing or learn from them because I was not familiar with some topics they engaged in (e.g., weathering, owl pellet). I also attended lecture-oriented class periods that aimed to transfer knowledge to students directly as well as to help students to recall what they have learned in the previous class periods. I observed that students were engaged with games in the last five to ten minutes of class periods when they had a quiz and an exam next day.

My role as researcher developed over time from passive participant to intermediate participant because if I were to become a fully active participant in the classroom, it would not be possible to capture the classroom members' everyday

interactions and behaviors, and answer questions about the meaning of their social actions. I maintained “the balance between being an insider and an outsider, between participation and observation” (Spradley, 1980, p. 60) by adjusting the level of my involvement in such a way that I participated in their activities gradually and asked fewer questions in order to avoid bothering the students. This strategy allowed me to build boundaries with the classroom members at the beginning and then they got accustomed to my existence and interaction with them over time. Thus, I was able to capture local circumstances in the classroom.

My field notes were written daily, depicting what happened in the classroom during my visit including my feelings, fears, expectations, and assumptions about ongoing cultural activities. My conversations with students and Ms. Corbin during class breaks and after classes were recorded in my field notes. Joining some groups and working with students allowed me to enhance my interactions with them and build connections. I had meaningful conversations with them about their classroom activities in advance. Two students were voluntarily taking care of the animals in the tanks in the classroom. During the breaks, I engaged in conversations with them about their classroom activities and their volunteered assignments.

My personal connections and interactions with five students and the teacher gave me additional interviews to learn and conceptualize the socio-cultural aspects of the classroom community in regard to participation, practice, community, accountability, social relationships, and classroom norms in the seventh grade science classroom. Semi-

structured interviews were conducted after school and audio-recorded with the same individuals.

I employed two data analysis methods: (1) the ethnographic data analysis method (Spradley, 1980; LeCompte, & Schensul, 1999) and (2) the constant-comparative method (Glaser & Strauss, 1967; Strauss & Corbin, 1998) to analyze data collected through participant observation and interviews respectively. Interviews were transcribed verbatim. Interview transcripts and participant observation were merged with the daily journals and artifacts (e.g., handouts, student presentations, and quiz/or test sheets) to delineate a holistic picture of the seventh grade science classroom from both emic and etic perspectives.

Vignette Introduction

In this section, I draw on two vignettes considered as “narrative snippets that crystallize illustrative issues in the field” (Graue & Walsh, 1998, p. 189). These vignettes emerged from my analysis of participant observation over several months, my field notes, and daily journals. I organized a list of vignettes that can be considered as data. With the reference to my research questions, I analyzed and organized them in a way that would portray a whole picture of what’s going on in the observed classroom. The two vignettes were here detailed: (a) to reflect the nature of school science practices; (b) to shed light on the interaction and communication structures between students and Ms. Corbin; and (c) to explore the social dynamics that determine the emergence of a community of practice in the science classroom. These two vignettes are important to help draw a picture of how I experienced the science classroom community. They are

also helpful to portray the classroom community's life, how students learn science, and how the teacher organizes and manages normative school science practices in order for students to understand scientific concepts. More specifically, the first vignette does so by addressing the regular classroom activities, whereas the second vignette focuses on the laboratory activities to describe interactions, practice and learning scientific concepts. I use these two vignettes as a means to establish a reasonable conclusion as to whether the science classroom turns out to be a community of practice.

Vignette 1: Presenting, Receiving, and Reproducing Readymade Scientific Facts

Ms. Corbin starts the class with a quiz as the routine work that students perform. It is about Deoxyribo Nucleic Acid (DNA) base pairing. Before the quiz, Ms. Corbin has students recall DNA structure, and they express 'twisted ladder' in their words, but they hear from their teacher its technical term 'double helix.' Ms. Corbin distributes quiz sheets. Each sheet has different DNA structure sample. Meanwhile, she reminds her students that they can gain extra credit if they write the names of four bases correctly. Tim asks what if he misspells the names of the bases because he states that the names of bases are not so familiar to him, and "they sound like technical terms." Ms. Corbin responds to him and other students as well, "Unless there are major misspellings, you can gain a credit." Then, students are given three minutes to complete their quiz. When students finish the quiz, Ms. Corbin picks a DNA sequence sample and writes it on the white board. She asks students, "What does Adenine (A) pair up with?" One student responds, "A pairs up with Thymine (T)." Ms. Corbin continues to ask, "What does Cytosine (C) pair up with?" Another student tells, "Guanine (G)," and so on. When Ms.

Corbin and students have finished to pair up the four bases (A, T, G, S), she lists and writes down the names of four bases on the whiteboard. At the same time, students self-check if the names of four bases are written correctly in their quiz sheet. However, Ms. Corbin does not collect their sheets in order to evaluate what they have done. Instead, she moves into the next activity.

After the quiz, Ms. Corbin distributes a two-page worksheet. The first page includes fill-in the blank questions regarding defects in meiosis and their consequences. She expresses that Down syndrome is a genetic defect. Individuals with Down syndrome have an extra copy of genetic material on the twenty-first chromosome. Meanwhile, she turns on the projector on the wall to exhibit a picture of chromosomes. She points to a chromosome having an extra on it. She continues to transmit information that individuals with Down syndrome have an average lower life span compared to those without it. While Ms. Corbin and students discuss Down syndrome as a genetic defect, Jaime shares color-blindness as another example of a genetic disorder. Even Jaime touches upon another genetic defect, Autism. She adds, "People with Autism are smart, but distinct from other people." Meanwhile, Ms. Corbin interrupts her and says, "There is still unknown about Autism, and scientists endeavor to explain details about this genetic disorder." As this conversation continues between Ms. Corbin and Jaime, the other classroom members listen to them and take some notes.

For the last 20 minutes, Ms. Corbin focuses the students on the second page of their worksheet. She asks the students, "How does DNA determine your traits?" She writes DNA and Ribo Nucleic Acid (RNA) on the whiteboard. She asks first, "What

does DNA stand for?” Tom says, “Deoxyribonucleic acid.” Then Ms. Corbin directly explains that the only difference between DNA and RNA is *deoxy*, which RNA does not have. Therefore, RNA stands for ribonucleic acid. She jots down the full names of DNA and RNA on the whiteboard. She asks the students to recall the four bases in DNA. She and some students altogether express and list down four bases—A, T, C, and G. At that moment, she directly expresses that RNA does not have T base; instead, it has Uracil (U) along with other three bases. Through recalling and reminding this information, Ms. Corbin establishes a ground for another activity. She begins writing DNA, mRNA, tRNA, protein, and traits on the white board, whereas the students are busy with writing notes about RNA and its four bases on their notebook. Then she asks them to take out paper and tells them, “Flip your paper in half vertically and then flip the other half in half again. You will have four columns.” Meanwhile she walks around and glimpses at students whether they have it as she wanted. She is back to the white board, and writes a sample of DNA sequence—CATGCTAAT—on the whiteboard. On each student’s paper, she wants to see four columns with headings for mRNA, tRNA, protein, and traits. She has them note that mRNA is a messenger RNA, tRNA is transfer RNA. She starts to say, “C in DNA sequence pairs up with G in mRNA. Then she asks Danielle, “A in DNA pairs up with what?” Danielle hesitantly says, “U?”, whereas other members insistently hold their hands to get permission to answer this question. Ms. Corbin reminds that “RNA does not have T base; instead it has Uracil.” She remarks it with a star on the whiteboard. She goes through a sample of DNA sequence by doing pair-up with the bases in mRNA and tRNA. Every time, she points to U base in RNA sequence.

When students finish pairing up bases, Ms. Corbin wants them to look up the information provided in their activity sheet to identify protein codes based upon triple bases in the tRNA sequence. When she does not get any response from them, she directly expresses that CAU sequence is called Valine according to the information in the activity sheet. She continues to tell, “GCT sequence is Argine and AAV sequence is Leucine.” She adds that these are the types of amino acids. Finally, Ms. Corbin has them imagine the whole sequence of DNA and its counterpart in tRNA sequence, and what kinds of amino acid are produced. Because students do not say anything, she directly expresses, “if we consider the whole sequence of amino acid, then let’s say your trait—hitchhiker’s thumb.” Students take for granted it and do not respond.

Vignette 2: Learning by Doing Some Practical Works

The members of the science classroom meet every Monday and Tuesday afternoons to perform practical works. Monday meeting lasts one class-period, whereas Tuesday meeting lasts two-class period. Ms. Corbin starts to tell students, “We did talk about the physical and chemical changes last week together” and adds “We will have a lab activity about these changes.” At that moment, a couple students’ expression “YES” mixes into the air. Before they begin doing their practical works, she reminds them of which students can work with whom. She says that Brit, Ted, Nicole, and Greg will work in the same group and so on. The formation of groups depends on students’ academic performance, behavior, and attitude. She forms different groups every several weeks. She distributes laboratory sheets to six groups of four students. She reads the first page of the laboratory sheet where lab purpose and procedure are written, and materials

are listed. While Ms. Corbin goes over the procedure section, she introduces to the students which materials and equipment will be used. Among the chemical substances in the material list are sucrose and sodium carbonate. She explains sucrose is sugar and sodium carbonate is baking soda. Thus, she makes them familiar with the daily uses of chemical substances. Then, she wants one student in the classroom to read the entire laboratory sheet before they start experimenting. While students hold their hands to read it, she selects Beril to read it because she seems to be a non-participant because she reads a novel in a quite manner. Beril reads the entire lab instruction step by step. When she finishes reading it, Ms. Corbin wants one student from each group to obtain goggles and gloves and the other student to get test tubes, chemical substances, spatula, and pestle. Two students in each group insist that they want to get these materials. Then each group is encouraged to determine other assignments (e.g., a leader, writer or recorder) in a group. An academically strong student in each group becomes a leader and guides the other students to become a writer. Students assigned to obtain experiment materials go to the bench in which Ms. Corbin has already put equipment and substances. At the bench, they start to talk to each other about which equipment they need to have, how many test tubes they will use, and which substances they first need to use. All of a sudden, the bench where they gather turns out to be a talk corner that includes discussion about daily life issues in addition to their lab activity. As a daily life issue, some talk about interactions with other students at a different grade level. Coming to the talk corner continues as long as they need to get the other materials.

Each group has students responsible for supplying laboratory equipment and materials, but their laboratory sheet has five mini investigations about the physical and chemical changes. Julie in one group takes the lead and asks who will do which investigation. At that moment, each member looks at the possibilities, and through quick personal and group decision, each one selects an investigation. They agree on each member's decision together. Meanwhile, another student, Terri becomes a recorder. Julie dominates the group and assigns herself as a writer. She also makes decisions about what to write after each investigation based on their observations. In other groups, similar roles and responsibilities emerge since two students have been responsible for obtaining lab equipment and supplying materials at the beginning, the other two students in each group develop leader and writer roles. In Brit's group, while he is a leader, Ted becomes a writer. Nicole and Greg are responsible for lab equipment and materials. They are encouraged to do their investigation in a collaborative manner by the teacher. The teacher reminds them that they are in the same group and should work together.

While each group is busy doing experiments and identifying the physical and chemical changes, Ms. Corbin stops by each group, checks what group members are doing, and asks at what stage they are. She continues to monitor the groups, whereas some group members ask her help to answer their questions in mind. She provides feedback. As necessary, she answers their questions directly. When she realizes that they completed the first page of the laboratory sheet, she wants them to pass to the second page where they will write their observations in a chart and explain whether they are physical or chemical changes in matters. In Julie's group, she as a leader asks the other

group members' thoughts and ideas before writing the group's findings. She puts forward her thoughts and ideas when other students do not share their ideas and thoughts; the other members agree. Therefore, it reinforces Julie's domination and control of the results. When they come to answer questions at the end of their laboratory sheet, Julie again leads the group to write down answers. The group agrees with what Julie says and accepts her final statements without discussing their own findings at each investigation.

Each group completely finishes experimenting, writing observations, identifying physical and chemical changes, and answering questions in the laboratory sheet. Ms. Corbin asks the groups to discuss similarities and differences between physical and chemical changes in another worksheet. She draws a Venn diagram on the whiteboard. She reminds students that they can benefit from their investigations and findings at their laboratory sheet. She picks Kevin to give an example, and he responds that eroding is a physical change. Another student, Rena disagrees with his example because she thinks that it is a chemical change. At that moment, some students agree with Rena and some do not. Ms. Corbin encourages these students to provide evidence and to explain why it is physical or why not. Disagreement on that example lasts a while and then is solved by Ms. Corbin. She concludes, "I think that eroding is an example for both physical and chemical changes." Ms. Corbin and her students continue to discuss other examples regarding chemical and physical changes until the bell rings.

Findings

I described two vignettes above to reflect the nature of interactions and relations among the classroom members, the roles they take on, and the practices they perform. I present the study findings with reference to the themes that emerged from my analysis of participant observation, field notes, interviews and vignettes. These themes are classified as: (a) normative practices and routine behaviors, (b) material and discourse resources, and (c) differential modes of participation accompanied with different roles and responsibilities.

Normative Practices and Routine Behaviors

In the seventh grade science classroom, different normative practices and routine behaviors emerged. On one hand, Ms. Corbin's normative practices were to set the agenda and orchestrate both regular classroom and laboratory activities. Students viewed her as knowledge transmitter and a source of knowledge. She used the power of knowing and the authority to determine, plan, organize, and implement the everyday activities of the classroom. On the other hand, students were viewed as the secondary actors in the classroom. They were expected to learn scientific concepts, gain scientific inquiry skills, connect scientific topics to their daily life, succeed in exams, and then be ready for new topics next year.

Different types of normative classroom practice directed students to act in different routine behaviors. When Ms. Corbin preferred using triadic dialogues (Lemke, 1990; Nassaji & Wells, 2000) to coordinate the regular classroom activities as exemplified in the first vignette, students' routine behaviors were limited to listening to

Ms. Corbin, receiving knowledge mostly from her and rarely from their friends, and taking notes. Yet, students were also actively engaged with laboratory activities to recall and verify knowledge represented in their textbook or by Ms. Corbin as well as to apply that knowledge and use inquiry skills in their practical works in the second vignette. Even though lab activities were simple hands-on activities where the students followed the prescribed procedures (Chinn & Malhotra, 2002), the students were expected to work and accomplish their task in a collective manner. While they performed the normative laboratory practices, they listened to their group members, developed strategies, shared their ideas, and made decisions together. Meanwhile, Ms. Corbin provided feedback, monitored their performance, and mentored them, but never partnered with them (Tabak & Baumgartner, 2004).

As part of her normative practices, Ms. Corbin intended to form different student groups in regard to sex, behavior, and academic performance every several weeks. She organized pair and small groups to regulate the laboratory activities where students were expected to work in a group. Working in a group encouraged students to divide their responsibilities and develop different roles. Ms. Corbin always monitored the students' group work as to whether they were working together or not. She encouraged them to do so when some were inclined to do laboratory activities individually or to dominate the activities. However, the working together norm was not socially constructed and negotiated among the members of the classroom community. Instead, Ms. Corbin reminded students when they worked in pairs and small groups. This norm was invisible and tacit until the members of the classroom community encountered unexpected

behaviors or attitudes. In other words, when students were engaged with laboratory activities in small groups, some of them intended to work individually and some of them did not want to divide their role and responsibility, and this in turn impacted group's collaborative work and group's decision about their findings and results. In addition, another reason why some students acted in an unexpected manner was that they were not assigned to work with their close friends in the same group.

Thus, Ms. Corbin displayed two different routine behaviors to regulate the classroom activities: (a) authoritarian and (b) facilitating. She adopted an authoritative manner when knowledge was transmitted to the students during regular classroom activities, on one hand. She was more facilitating during laboratory activities where students were the center of action, on the other hand. Her authoritarian side enforced the students to accept the norms, or rules to become a member of a group, implement their classroom activities, and sustain their participation and membership. In that regard, I viewed her expectations as desired behaviors or social norms (Evertson, Poole, & the IRIS Center, 2003; Loh, Marshall, Radinsky, Mundt, & Alamar, 1999). Included among the social norms appeared to be being silent, raising hands for taking a turn to speak while performing regular classroom activities, and working together with a division of labor during lab activities. All of which were essentially part of this classroom community and a means to sustain learning and participation (Good & Brophy, 2000; Sergiovanni, 1994). As exemplified in the first vignette, the main purpose of performing the regular classroom activities was to present knowledge, and to allow students to receive and reproduce ready-made scientific facts. Students needed to act as the obedient

of the rules or norms in order to acquire knowledge. However, they were more flexible when they were engaged with laboratory activities described in the second vignette because they were the center of action. They were motivated to make their own decision in order to perform their activities. Although their teacher was the one who familiarized students with these norms, they were expected to obtain these norms in order to adapt to the culture of the classroom and perform their contextual practices.

Material and Discourse Resources

Material resources. The material culture of the classroom community included one computer and one projector as equipment. Ms. Corbin used them for Microsoft office program applications (e.g., word processing and Power Points) and to connect to the Internet. The presence of the Internet-connected computer and a projector allowed her to present knowledge for transfer and implement instructional activities. These technologies were a means for the teacher to monitor student's readiness to quizzes and exams as well as to disseminate ideas, concepts, and terms easily. As exemplified in the first vignette, the teacher used the projector to exhibit the picture of chromosomes in order to enable students to imagine and conceptualize how and what conditions people are born with such Down syndrome. The projector was a tool for her to draw students' attention to the topic and concentrate on the picture displayed. The projector was also a means for the students to present their projects with the classroom community members. Students had projects to present over two semesters. Although some groups prepared their poster to do so, some prepared their Power Points by using different animations and visual effects to draw their peer's attention. Therefore, these technologies were shared

among the members in order to facilitate teaching and learning scientific concepts throughout their contextual practices.

The material resources encompassed handouts provided by Ms. Corbin to guide and support student learning. Since Ms. Corbin prepared both regular classroom and laboratory activities, students were seldom required to design materials (e.g., DNA models). Handouts regarding the regular classroom activities included worksheets, quiz sheets, and course notes as illustrated in the first vignette. These handouts pertained to knowledge presented in their science textbook. As illustrated in the second vignette, students were provided with laboratory handouts. These handouts listed the purpose, the procedures, and the materials. The students were also provided with laboratory materials and equipment (e.g., microscope, pH meters, gas pressure sensors, and balance) to conduct their scientific investigations and complete their lab assignments. These material resources were the shared repertoire in the classroom community where students performed both regular and lab activities to learn scientific concepts.

The material culture of professional science communities includes inscription devices, detectors, artifacts, and physical/conceptual/computational models (Latour & Woolgar, 1986; Lynch, 1985; Nersessian, 2009; Pickering, 1995; Traweek, 1988). These elements play a major role in the process of knowledge generation and the re-production of the community itself. Inscription devices provide scientists with inscriptions that would be operationalized to be a taken-for-granted fact (Latour & Woolgar, 1986). Detectors are mnemonic devices that physicists use to perform their practices and generate new detectors to constitute a discovery (Traweek, 1988). Physical or conceptual

or computational models are the components of epistemic activity in engineering communities (Nersessian & Patton, 2009). The material culture in the classroom community included worksheets, predetermined relevant materials and equipment. I observed that the classroom instructional materials or equipment were fixed and ready to use for its users. Both the teacher and the students believed that these materials or equipment are key tools, and these are shared to perform their contextual practices. Thus, these materials were a set of resources (i.e., a shared repertoire) that the classroom community members used to understand scientific concepts and topics.

Discourse resources. In logs of my field notes, I typically noted many scientific and technical words/terms. Using vocabulary worksheets Ms. Corbin brought these terms to the students' attention. She lectured and discussed these terms during the whole class sessions in which the Initiation-Response-Evaluation (I-R-E) and Initiation-Response-Feedback (I-R-F) interactional patterns took place. That is, she preferred initiating a question about a term, students responded to that question, and then she evaluated their response or provided feedback (Mortimer & Scott, 2003; Oliveira, 2010). In addition to using vocabulary sheets and lectures, the scientific and technical terms were shared with the students through a variety of games. Among the games were "Who wants to be a millionaire," "Bell Ringer," and "Bingo." The students were familiar with the games from their daily life; therefore, it was easy for Ms. Corbin and the students to use them in the classroom. Students perceived these instructional materials as stimulus tools to get higher scores in science exams because these games stimulated for them to remember and learn scientific concepts, terms, and meanings a bit easier. In addition,

they were also tools for Ms. Corbin to facilitate students' understanding of these terms and to encourage some marginal students to participate in the classroom activities.

These resources that integrated science vocabulary and popular games allowed the students and Ms. Corbin to learn science. For instance, when the students were engaged with laboratory activities, they used the scientific terminology in the games to write up their laboratory reports and exams sheets. The teacher used the games to simulate students' motivation before the exams and quizzes. The games helped students learn about the scientific terms and concepts as they were enjoying their time.

Vocabulary sheets and games were a set of resources that the classroom community members used to acquire and recall scientific knowledge. Science vocabulary sheets were prepared and determined by Ms. Corbin, though games were established through mutual negotiations between the teacher and the students. In other words, some students brought games to the classroom community. Ms. Corbin liked the idea and used them to support and sustain student learning scientific concepts and terms. Regardless of who developed these resources, how they were established, and for what purposes they were used, both resources have become a shared repertoire in the classroom community. The classroom community members got accustomed to use them as the common resources over time.

Differential Modes of Participation Accompanied with Different Roles and Responsibilities

I observed different modes of participation established by Ms. Corbin: (a) individual mode, (b) pair mode, (c) small-group mode, and (d) whole-class mode. Ms.

Corbin and her students took on different roles and had different responsibilities as they participated in their contextual and shared practices.

By *individual mode of participation*, I refer to the interactions between a student and a teacher (Philips, 1972; Olitsky, 2007; Jocuns, 2009). In this type of participation, all students worked individually under Ms. Corbin's guidance. Ms. Corbin usually gave them an assignment to complete. Ms. Corbin acted as an authoritarian figure, and checked and controlled students' behaviors and attitudes to teach scientific topics. However, students were allowed to ask questions if there was anything unclear to them. When students had questions, they called on Ms. Corbin because she was the only one responding to their inquiries. They received the necessary information from Ms. Corbin. Thus, the individual mode of participation transformed the students into receiving objects (Freire, 2000).

Pair mode of participation can be attributed to the interactions between two students under Ms. Corbin's guidance. It was different from the individual mode of participation in that students in pairs shared their understanding, experience, knowledge, competence, and responsibilities. Meantime, Ms. Corbin was in the role of facilitating. When a pair group had a conflict or a disagreement, Ms. Corbin helped them out through feedback. The pair mode of participation occurred as students were engaged with both the regular classroom and laboratory activities. For example, when designing a solar oven model, Ms. Corbin set pairs who would decide their own best model to cook something. Students were encouraged to negotiate how to design a model, what kind of materials they would use, and how to use the model to conduct their investigations.

While students were the center of action and discussed each step to design the model by sharing their ideas, Ms. Corbin monitored each group, provided feedback, and checked their performance. Students in pairs acted in a collaborative manner as they mutually communicated their ideas with each other and shared with each other the power of knowing and the experience that helped them accomplish their assignment. In addition, they were in symmetric interactions (Roychoudhury & Roth, 1996) where no one dominated their conversation, which in turn developed the sense of ownership of a solar oven model (Oliveira, Sadler, & Suslak, 2007a; Polman, 2004; Tabak & Baumgartner, 2004).

Small-group mode of participation is when students work in a small group with more distant teacher supervision (Philips, 1972; Jocuns, 2009). In this type of participation, Ms. Corbin was in the role of mentoring each group and supporting their articulation of ideas among the students in each group (Tabak & Baumgartner, 2004). Ms. Corbin frequently initiated the small-group mode of participation when students frequently performed laboratory activities. Given that students were the center of action, they were responsible for doing their own investigations. To accomplish their lab assignment, they were provided with the opportunity to determine the division of labor in each group. Although they were not urged to be in the pursuit of the unknown, they worked and completed lab assignment collectively, and negotiated their conflicts and disagreements with regard to investigations, observations, and findings. In turn, their mutual negotiations led to transforming their disagreements into agreements.

In the small-group mode of participation, students sustained the mutual and joint understanding and the re-production of meaning through symmetric and asymmetric interactions (Roychoudhury & Roth, 1996). The symmetric interactions were centralized when members of a group shared their roles, determined their responsibilities, and committed themselves to pursuing their investigations. Asymmetric interactions occurred when there was a leading, dominant, and more knowledgeable peer in a group. In asymmetric interactions, non-participant (marginal) students respected and trusted the leading person's knowledge and competence.

Whole-class mode of participation can be attributed to the teacher-initiated whole class interaction where the teacher dominates her social and epistemic authority to orchestrate the classroom practices and maintain continuous science learning (Jocuns, 2009; Turpen & Finkelstein, 2010). In the whole-class mode of participation, Ms. Corbin was the center of action; therefore, she established asymmetric interactions with students. She was in the role of leading conversations, transmitting knowledge to the students, and motivating the marginal students to engage in discussions through asking rhetorical and literal questions. Meantime, many students voluntarily participated, listened to her, and rarely raised questions. Ms. Corbin preferred to employ the IRF sequence to manage the whole-class interactions. The IRF sequence motivated students to participate in a conversation and discuss scientific concepts. Yet, the IRE sequence existed when students were engaged with question-answer routine activities (Lemke, 1990).

Discussion

Findings indicate that the teacher played the primary role in organizing and implementing the normative practices of the classroom community. Students were expected to adopt the social norms of the classroom community to learn scientific concepts and succeed in science exams. Students were provided with the opportunity to engage in the regular classroom and laboratory activities. A variety of games were employed to allow students to recall and memorize scientific concepts for their quiz and exams, and they competed with one another as the teacher raised questions during the games. The teacher was the center of action during the regular classroom activities because the teacher wanted to transfer knowledge to students. However, laboratory activities were more student-centered, and students were encouraged to develop roles, divide their responsibilities, and work together in order to accomplish their lab assignments. In this study, I did not aim to evaluate the seventh grade science classroom community as to whether it was different from any conventional science classroom community. Instead, I aimed to determine its own cultural features that enlighten its contextual practices, the roles and responsibilities of the members, and the nature of participant structures. To do so, I sketched two vignettes and described the teacher's instructional strategies to teach scientific concepts and to contribute to student learning in regard to the social norms, the material culture, and differential participations. In this section, I use these informative findings to reveal and explain the potential barriers to and opportunities for the emergence of a classroom community of practice and to discuss

in what ways they impact our understanding of a science classroom as a community of practice.

Barriers to the Emergence of a Classroom Community of Practice

As is known, the main idea in communities of practice is to move beyond the study of individuals alone; to consider how learning occurs within the social context (Bielaczyc & Collins, 1999; Brown et al., 1989; Collins, 2006). Learning occurs by developing identities in the context of a shared practice rather than replicating others' performance (Lave & Wenger, 1991). Individuals learn through collaboration and social interaction in communities of practice when they are engaged in authentic tasks to solve real-world problems (Brown et al., 1989). Yet, I observed some barriers to the emergence of a community of practice in the science classroom. I construe this circumstance in regard to power relationship, practice, participation, community, and interpersonal teacher behavior.

Power relationship. Participation in social context encompasses negotiations among individuals for sharing and shifting power to continue their contextual practices (Berry, 2006). The negotiation process itself is a crucial aspect of a community of practice (DePalma & Teague, 2008). In this study, the seventh grade students accepted and internalized that their teacher was the one who plans, organizes, and implements their classroom practices as well as initiates their common goals (e.g., particularly learning and memorizing scientific concepts, having fun, and being successful in science exams) through her power and authority as a component of classroom life (Pace & Hemmings, 2007). Roberts (2006) views the power as “the ability or capacity to

achieve something, whether by influence, force, or control” (pp. 626-627). The teacher I observed had an influence over students’ actions, behaviors and learning activities. The students became obedient to the rules, routines, and regulations in the classroom. Yet, this situation restricted their mutual communication on power sharing or shifting. It also overlooked collective authority that allows the classroom members to generate, develop, and negotiate their own agenda together, that is, a joint enterprise (Wenger, 1998). The students could not get ownership of rules or social norms to perform their activities. Hence, power relations between the teacher and the students were stable, and the constructed *power* in the classroom was institutionalized. In other words, it was already given to the teacher (Bauchspies, 2005; Oliveira, 2010).

Throughout the course of this study, I observed two different personalities of the teacher: (a) authoritarian and (b) facilitator or regulator. Somehow these personalities problematized power sharing in the classroom. On one hand, her facilitator personality allowed students to actively interact with each other and have more freedom and flexibility to perform their activities in their group. She tended to establish a synergic learning environment in which the students collectively decided on what to do, and the teacher monitored their activities and mentored them by providing feedback and suggestions. On the other hand, the teacher was reluctant to share the power with the students, and her authoritarian personality controlled students’ investigations, behaviors, and attitudes. She reinforced her authoritarian figure in a way that determined what students should learn and perform the next day (Hayes, 2002; Oliveira, 2010). This situation discouraged her to conceive of the students as contributors (Lensmire, 2000;

Tabak & Baumgartner, 2004). Nonetheless, sharing power of knowledge and knowing and exchanging experience with the students would have increased the feeling of unity among students, and would have fostered their membership to the classroom community (Olitsky, 2007). They would have developed and had a sense of ownership over their learning practices (Oliveira et al., 2007a; Polman, 2004; Tabak & Baumgartner, 2004), and would have supported each other's social accomplishments (Engle & Conant, 2002). In that regard, it seems that there is a need for “new cultural tools (i.e., new participant structure) [that] transforms power and authority” (Wertsch, 1998, p.65). Hence, I suggest developing a new participant structure that will allow students to socially construct a particular set of possible relationships among the members, to respect different degrees of knowing and competence that the members have, and to trust each other's background and experience, all of which will then enhance the emergence of a community of practice in the classroom.

Practices. Practices are the patterned activities in which individuals participate to understand natural phenomena around themselves (Roth, 1998). I classified practices the students performed into two types—regular classroom activities and laboratory activities. As exemplified in the first vignette, students were engaged in the traditional (or regular) classroom activities by: (a) completing worksheets and assignments through the teacher's knowledge, (b) going over handouts and having mini discussions, and (c) taking quizzes and exams. In these activities, there was no sense that students would gain the ownership of their learning and understanding because they were assigned to stable practices. In addition, they were directed to recall and memorize scientific

concepts and terms to get higher exam scores. These activities only allowed them to reproduce knowledge and be familiar with science subject-matter to apply in their laboratory activities (Chinn & Malhotra, 2002).

Additionally, students were engaged with a variety of games I classified as the regular classroom activities since the games were aimed to support students' acquisition of scientific knowledge and terms. Games were more appealing to them because they were in competition with their peers and having fun in science. As described in the second vignette, the laboratory activities were more tempting to students in the sense that they did hands-on activities, used some inquiry skills (e.g., observation, experimenting, collecting data and transforming data into charts), and actively interacted with their peers. However, these activities were mostly well-defined and structured. There was no opportunity for students to pursue an unknown, because they had to follow instructions and find the expected outcome. These activities did not encourage them to participate and commit themselves to answering a question posed in any specific laboratory activity because they knew their teacher had the answer for that question, and all they had to do was follow the instructions (Roth, 2006; Høngström et al., 2010).

Occasionally, open-ended lab activities (e.g., solar oven) were provided to students and connected to their daily life. Even though laboratory activities were not similar to authentic tasks in scientific communities (Brown et al. 1989; Edelson, 1998; Chinn & Malhotra, 2002; Weinstein, 2008), students' participation and motivation was at the high level, and they were willing to engage in the safe version of real science (Archer et al., 2010). These outcomes were consistent with the school's goal in a way

that aims to cultivate students with strong academic background. However, their classroom practices were not evolving over time in line with the classroom members' temporal goals, purposes and intentions as well as their educational experiences. Instead, they were fixed and designed to teach 'normal science' (Kuhn, 1996). As a result, their classroom practices did not exemplify the science classroom as a community of practice.

Participation. Participation or engagement in activities is viewed as a means for individuals to become an active participant (Wenger, 1998). In other words, participation is a process in which a peripheral participant transforms into a full participant in a community over time (Lave & Wenger, 1991). In this study, the degrees of students' participation were dependent upon the activities offered by the teacher. She orchestrated the classroom practices by establishing four different modes of participation. The individual mode of participation and the whole-class mode of participation were to enhance the individualistic learning through the questions-answer routine works (Lemke, 1990). These works were yet a vehicle for students to memorize scientific concepts as well as to reproduce ready-made scientific facts (Latour, 1987), which in turn played a significant role in students' understanding and performance in science exams. In addition, the individual mode of participation restricted the students to interact and communicate with the other classroom members because they were only in contact with the teacher.

Through the whole-class mode of participation, some students became marginalized in the classroom community because their participation was voluntary. This situation was a factor that might deprive these students from the social and

academic benefits of the classroom community life (Gitlin, Buendia, Crosland, & Doumbia, 2003). Thus, establishing these two modes of participation was a barrier for the students to develop “the intellectual roles and audience roles” for science classroom discourse (Herrenkohl & Guerra, 1998, p.455; Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999) as they participated in classroom practices because they were not provided with the opportunity to discuss their thoughts and ideas in such a way that they convinced their peers. Nevertheless, if these students had been encouraged to participate in collectively developing a shared repertoire (e.g., artifacts, accumulating collective knowledge), organizing their activities, and socially constructing dynamic participatory roles, they would have transformed their participation from the peripheral to the center. In turn, the classroom community itself would have moved toward a community of practice (Kovalainen & Kumpulainen, 2007; Olitsky, 2007; Roth, McGinn, Woszczyna, & Boutonne, 1999).

Community. In the small group modes of participation, students intended to work with their close friends because they have common histories and are aware of their good and bad sides over time in the classroom. They have been together in the same classroom for three years. Working with the close friends would make them feel a part of their group (or sub-classroom community). However, these groups were configured and reconfigured by the teacher. The situation led students and the teacher to develop a different intent to perform their classroom practice. While the teacher intended to have heterogeneous groups in terms of students’ academic performance, sex, and behavior, and to motivate them to work in a group, students tended to work individually and

minimize their interaction with others in a group. In turn, it discouraged their belongingness to a community in general and a group in particular, and jeopardized their social relationships in a group. Conversely, belonging is associated with student engagements (Osterman, 2000; Watson & Battistich, 2006) and institutional identities of students (Eckert & Wenger, 1994; Ferrari, McCarthy, & Milner, 2009). In this view, Freeman, Anderman, and Jensen (2007) note that students with a sense of belonging in a particular group can develop mutual goals and beliefs to sustain their learning and participation in classroom practices. If the teacher and students mutually establish and negotiate their joint goal, then students' engagement in a shared activity will increase and their feeling of being part of a community will be endorsed.

Interpersonal teacher behavior. Interpersonal teacher behavior can be explanatory to cultivate or deconstruct a community of practice in the science classroom. Interpersonal teacher behavior describes communication style along two dimensions: influence (dominance-submission) and proximity (cooperation-opposition). Influence describes the degree of the teacher's control over what goes on in the classroom. Proximity points to the degree to which interactions between the teacher and students occur in harmony or disharmony (den Brok, van Tartwijk, Wubbels, & Veldman, 2010). In this study, I observed that the teacher always displayed her control and dominance over the students and activities during the individual and whole class modes of participation. She was in the manner of checking and maintaining the students' behaviors, and managing the social norms. In these modes of participation, the students were provided with less opportunity to share the responsibility with the teacher. This

situation minimized cooperation with students as well as freedom. Thus, more dominance and less cooperation motivated the students to become more individualistic, competitive, and isolated learners rather than collectivist, collaborative learners in the classroom community.

Opportunities for the Emergence of a Classroom Community of Practice

The social structure of school science classrooms guides and shapes our understandings of relationships and interactions, and roles and identities developed within the context of school science practices (Aschbacher et al., 2010; Olitsky et al., 2010). Here, I highlight and discuss the opportunities for the emergence of a classroom community of practice in terms of participation, identity, and community.

Participation. As mentioned in the findings section, the teacher organized the four modes of participation to facilitate student understanding of scientific concepts and terms. Only the pair mode of participation and the small group mode of participation provided students with the opportunity to be the center of action, establish different roles, share responsibilities to perform their contextual practices, and develop a collective understanding of a shared practice. Especially in the small-group mode of participation, the students more actively engaged in laboratory activities. They often encountered disagreements, conflicts, and multiple perspectives from each other. They were motivated to evaluate each one's work. Their conflicts and disagreements were overcome among the students through the interpersonal engagements in their group assignment. Therefore, their mutual interactions were a means for each student to

identify “who is who, who is good at what, who knows what, who is easy or hard to get along with” (Wenger, 1998, p.95).

Identity. The small group mode of participation allowed the students to transform their interactional roles from a listener or a knowledge receiver, to a leader or a translator, or an inquirer as well as to a knowledge challenger. Taking a leader role was associated with the academic performance and topic of interest among students. Taking a translator role was a temporally emergent strategy to help a peer struggling with speaking in English in a group. The small group mode of participation through open-ended laboratory activities and discussions encouraged the students to challenge the teacher’s knowledge or knowledge represented in their textbook (Bloom, 2006). Taking a challenger role was a stimulus for them to bring up more questions to the table, and interact and collaborate with their group members to resolve their question. These opportunities enhanced their learning and co-construction of their understanding of scientific concepts. However, their roles or identities were not ever transformed into a teacher role or identity (Boylan, 2010); instead the different roles they developed motivated them to actively participate in the classroom activities. Their active participation helped them become familiar with and acquire scientific knowledge and gain inquiry skills to accomplish their task (Clark, 2005), which in turn established intellectual identities (Engle & Conant, 2002; Greeno, 2002).

The formation of small groups based on students’ academic performance, behaviors, and attitudes encouraged them to be cognizant of their knowledge, skills, and experience. In turn, it fostered student-student relationships that increase the solidarity in

a group (Olitsky, 2007; Tobin, 2012). In that regard, their interactions and mutual agreements or disagreements throughout the laboratory activities in regard to determining each member's role and responsibility, doing investigations, writing lab reports, and designing their projects pushed them to work together and trust each other. This type of formation was to augment a shift from marginal participants to peripheral participants, and peripheral participants to full participants over time in student groups (Lave & Wenger, 1991). This transformation in degrees of participation was to support students' feeling of belongingness to a group, though each student group was re-formed and re-structured by the teacher.

Community. The teacher used two different strategies to enhance student's commitment to the classroom community and student engagement. First, in the whole-class mode of participation, she preferred using the inclusive pronouns (e.g., we or our). Using the inclusive pronouns was a way to make the classroom members feel united in the classroom community. The use of these pronouns was a reminder for the students that they were part of the community (Moje, 1995; Oliveira, 2011). Second, she used the exclusive pronouns (e.g., you or your) when the small group mode of participation was centralized. The use of exclusive pronouns was to promote the group membership. They could do their contextual practice communally. They sensed that they pursued a shared goal. Hence, the use of both exclusive and inclusive pronouns was a stimulating tool to motivate students' membership to their group in particular or the classroom community in general. These pronouns were to help transform their participation in classroom practices and discourse over time (Enyedy & Goldberg, 2004), and were a means to

establish and foster egalitarian social relationship among the classroom community members and facilitate their whole-class discussions (Oliveira, 2011).

Concluding Remarks

In this study, the main purpose was to explore and document everyday activities of a classroom community and to delineate the social dynamics that impact the emergence of a community of practice in school science context rather than to criticize and denigrate the teacher's teaching and instructional strategies to sustain teaching and learning science. To accomplish this purpose, I drew on communities of practice notion addressing the collective activity between the person and the social world. This notion refers to a social learning system that has complexity in such a way that its each element (e.g., social agents) is dependent on one and another. The absence of one element can destroy the system itself. Complexity metaphor in within communities of practice notion can be described by the four main constructs: (a) practice, (b) community, (c) meaning, and (d) identity. As individuals participate in a shared practice within a community, they transform their participation from periphery to the center, and they move from newcomers to old-timers over time. Meantime, they develop a collective understanding and construction of an activity. In this study, I looked at the four constructs as to whether a community of practice emerges in a science classroom. I sketched two vignettes to highlight the normative science classroom practices and to discuss them in regard to authenticity since individuals engage in authentic tasks consistent with real-world problems as their ordinary practices in a community. As exemplified in the vignettes and presented in the findings section, normative classroom practices are stable and

predefined to help students acquire scientific knowledge in order to succeed in science exams. These practices are mostly performed to recall and memorize knowledge represented by the teacher or in the textbook and verify and apply that knowledge in laboratory activities.

Community construct is simply associated with social relationships, mutual goal, and shared norms, beliefs, and resources the classroom members use to perform their contextual practice. Although the teacher established different participation modes to enhance student engagement in activities, social and epistemic authority were not distributed to determine the classroom community's norms collectively. Students' groups were formed by the teacher's preference. This in turn minimized students' willingness to work together and feelings of belonging to a group. As mentioned in Wenger et al.'s (2002) study, the classroom community should include both an intellectual competence and a belonging. The classroom practices may have allowed students to develop an intellectual competence, but the teacher's authority over student learning, group formations and norm constructions was barrier to develop a sense of belonging to a group or a classroom.

Meaning construct refers to students' experience with scientific knowledge, concepts, terms and natural phenomena individually and communally as they engage in school science practice. They made sense of natural phenomena presented in school science context through social relationships established by the teacher during the regular classroom activities. Yet, students were able to establish their social relationships and negotiate their experience in the laboratory activities under the auspices of the teacher.

This contradiction resulted from the teacher's two different personalities that could be determinant for the absence of a community of practice in the classroom.

Identity construct is about a process of becoming. Learning occurs as individuals transform their roles. For the teacher, she shifted her role from a teacher to a mentor when students were engaged with laboratory activities. At the same time, students moved from a listener and knowledge receiver to a leader, translator, and inquirer. In contrast, the teacher did not conceive of students as contributor when they were bombarded with scientific knowledge and concepts during the regular classroom activities. This duality in turn problematizes the emergence of a community of practice because of sharing power issue. However, if the teacher adopted a mentor role for herself, and conceived of students as her apprentices who would go through a trajectory of becoming a mentor, I would not observe such a duality in the classroom. Students would enter the community from the periphery and move towards the center as they take on the role of mentor (Bloom, 2006).

It seems that the complexity addressing the four constructs is not established well in the observed classroom. This study simply reveals that barriers emerged in the cultural events jeopardize the emergence of a community of practice in the classroom. Nonetheless, barriers and opportunities co-exist in the science classroom to understand the emergence or absence of a community of practice. These are a lens for science education researchers and teachers to review, revise, and reconceptualize the elements of classroom community life (e.g., power, practice, participation, teacher-student relations, or social positions) in order to develop a community of practice in science classrooms. In

addition, these are a means for designing a new participant structure that connects student activity to practices, interactions, and communication patterns of communities of practice.

This study has two limitations. First, it investigated only one science classroom to determine the social dynamics that support or hinder the emergence of a community of practice in school science context. Due to time, location, and availability this initial study included only one science classroom; however, the time spent in the classroom extended over the entire year. Hence, I suggest examining two or more classroom contexts in order to capture differences and similarities in teachers' instructional and teaching strategies to explore learning science and interpersonal teacher behaviors that shape student-teacher relationship, their positions, and actions in the classroom community. Second, this study drew on the qualitative data collection techniques such as participant observation, interviewing, taking field notes and daily journals, and collecting artifacts. However, the use of videotaping and video analysis would have provided a more precise documentation of the social relationships between the teacher and students, to understand the communication system, to elicit interaction patterns in the classroom community, to reveal the classroom members' behaviors and attitudes, and then to analyze them from multiple viewpoints.

CHAPTER V

SUMMARY

This dissertation draws on anthropological and sociological approaches to understanding the distinct characteristics of school science and science communities. This dissertation is grounded by two qualitative methods: (a) meta-ethnography, and (b) ethnography. Meta-ethnography is used as a mode of inquiry. It is a means to explore, examine, and compare concepts or ideas in ethnographic studies to make a synthesis. It is interpretive in a way that allows the potential audience to translate the synthesis into their understanding. Ethnography is another mode of inquiry that provides a holistic picture of another culture from etic and emic perspectives. It allows us to learn from members of a particular community about their cultural knowledge to continue their daily activities, their relationships with one and another, and their values and norms to sustain their membership in the community. It provides a lens for understanding the socially constructed beliefs and meanings in school science and science communities.

Chapter II investigates the three ethnographies of science to explore the features of scientific practice and interpret how science is practiced. It highlights and translates the emerging concepts across the three ethnographic studies of science and synthesizes the prolific aspects of scientific practice (Latour & Woolgar, 1986; Lynch, 1985; Traweek, 1988). It reveals two converging themes: material culture and discursive activity. The material culture is essential to perpetuate doing science and reproducing the community. In other words, the practice of science and community change and renew as

the material culture evolves. Discursive activities are inherent in the organization of science. Discursive activities are significant agency in knowledge generation process and community transformation. Chapter II also points out that a laboratory is an evolving, complex system because it is a physical space for conducting experiments, and generating and using artifacts and it is the social organization where a particular group of people engage in a shared practice, actively communicate with each other, and share a mutual goal to accomplish their task. Its social structure changes as the material culture evolves.

Chapter III explores the culture of a scientific-engineering community and the sociocultural characteristics of the community members' interaction. It analyzes how the community members work in collaboration as they conduct their research. It highlights how the community members negotiate and mutually agree upon as they interact and communicate with one another. It elicits how the research groups' members learn and sustain performing their contextual practice in engineering research. It reveals that faculty members' working styles lead the formation of research groups that supports learning and research. Communication and interdisciplinarity in the community initiate collaborative partnership and allow the members to generate a shared repertoire to continue to do their contextual practices. It points out that mentorship is a social mechanism for transformation of participation in the community. It concludes that the community members' activity has the cognitive, material, and socio-cultural dimensions that help the community members understand natural phenomena in the virtual world as well as perpetuate learning and research. The social accomplishment in the community

depends not only on how well the community members perform their contextual practice, but also on how well they recruit newcomers and how well they maintain their collaborative partnership to continue research and cultivate engineering researchers.

Chapter IV explores the social structure of a science classroom community, investigates social dynamics that support or hinder the emergence of a community of practice in school context. It highlights normative practices and routine behaviors, material and discourse resources, and participation modes that characterize the science classroom community. It points to some barriers to the emergence of a community of practice. Power of knowledge and knowing is not shared with students. Activities students perform lack authenticity. The teacher dominates the individual and whole class modes of participation. The teacher's control dominance over students and activities minimize students' commitment to the classroom community. All of which are determinants that hinder the emergence of a community of practice. However, the teacher provides some opportunities to support the emergence of a community of practice. Forming the small and pair modes of participation are ways to allow students to work together, learn each other's knowledge and competence, gain ownership of their ideas, develop roles, and perform a shared practice through mutual engagements.

In conclusion, Chapter II reveals that the three ethnographies of science are a means to understand the local knowledge generation, the efficacy of scientific facts in the community, and reproduction of scientific communities. The material and discourse dimensions of scientific practice are the evidence that can help support the intersections between communities and science education communities to design learning

environments. These dimensions are windows for us to situate authenticity in learning environments. Authenticity refers to bringing the elements of scientific practice into learning environments where students are engaged with activities, such as generating and accepting of fact-like statements (Latour & Woolgar, 1986), transforming disagreements into agreements to determine the reliability of data (Lynch, 1985), and building and rebuilding laboratory instruments to renew and transform the community as well as to constitute scientific discovery (Traweek, 1988).

Chapter III highlights the social relationships, mutual engagements, social practices, and strategies for sustainability in research and learning within the social organization of the scientific-engineering community. It extends our understanding of research and learning in a complex system where the researchers constantly learn during their engineering problem solving activities. They initiate collaboration in the community and across other communities to pursue the originality in engineering; newcomers transform their participation in the community over time; and they build solidarity to collectively learn and conduct their research in the community. These features are a means to develop and design learning environments where students perform authentic tasks through special technologies and methods.

Chapter IV focuses on a social learning system of a science classroom. It helps us understand and conceptualize the distinct features of science learning and teaching within the context of communities of practice. It draws a picture that the classroom community has its own social organization that allows its members to perform their contextual practices. It shows that the teacher's style to manage science learning and

teaching is the determinant as to whether a community of practice develops in a school science context. Activities offered to students are the way students learn science in the classroom community. Interpersonal relations among the community members show the way they sustain their communication and participation. All of which provides a valuable resource to redesign science learning environments.

Overall, three studies bring to the fore insightful perspectives emerging from the past science communities, the present scientific-engineering community, and the school science community. These perspectives shed light on individuals' everyday activities in their own community. I observe that there are differences among the past three science communities and the present scientific-engineering community in regard to the material culture. The three ethnographic studies of science examined in Chapter-II reflect their community and specially-designed technologies used to perform scientific practice at the laboratory bench. The scientific-engineering community has developed its own social structure to perform their practices in the virtual environment because the current technologies allow them to conduct their investigation in the virtual environment. Therefore the three science communities studied by Latour and Woolgar (1986), Lynch (1985), and Traweek (1988), and the scientific-engineering community that I studied have their own specially-designed technologies upon which science and engineering researchers depended and trusted to carry out scientific investigations. Science and engineering researchers were part of a community that they commit to. This community had a complex, evolving learning system that includes cognitive, material, and socio-cultural characteristics. In contrast, the school science community has its distinct

characteristics. The members of the community perform activities to learn scientific knowledge. The teacher determines its social structure. Under the auspices of the teacher, the members use more simple technologies and ready-made scientific facts to understand and conceptualize natural phenomena represented in the classroom community. Although there are differences among the communities examined in this dissertation, these differences and other aspects are valuable to contribute to the efforts for designing authentic learning environments.

REFERENCES

- Abell, S. K., Dillon, D. R., Hopkins, C. J., McInerney, W. D., & O'Brien, D. G. (1995). Somebody to count on: Mentor/intern relationships in a beginning teacher internship program. *Teaching and Teacher Education*, 11(2), 173-188.
- Aguilar, O. M. (2009). *Examining the community of practice framework in environmental and science learning contexts with Hispanic youth*. Unpublished doctoral dissertation, Cornell University, New York.
- Aguilar, O.M., & Krasny, M.E. (2011). Using the community of practice framework to examine an after-school environmental education program for Hispanic Youth. *Environmental Education Research*, 17(2), 217-233.
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.
- Anderson, E. M., & Shannon, A.L. (1988). Toward a conceptualization of mentoring. *Journal of Teacher Education*, 39(1), 38-42.
- Angrosino, M., & Rosenberg, J. (2011). Observations on observation: Continuities and challenges. In N.K. Denzin, & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (4th ed., pp. 467-478). Thousand Oaks, CA: Sage.
- Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, R., & Wong, B. (2010). Doing science versus being a scientist: Examining 10/11-year old school children's constructions of science through the lens of identity. *Science Education*, 94, 1-23.

- Aschbacher, P.R., Li, E., & Roth, E.J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering and medicine. *Journal of Research in Science Teaching*, 47, 564-582.
- Ayar, M.C., & Yalvac, B. (2010). A sociological standpoint to authentic scientific practices and its role in school science teaching. *KEFAD*, 11(4), 113-127.
- Barab, S.A., & Duffy, T.M. (2000). From practice fields to communities of practice. In D.H. Jonassen, & S.M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 25-55). Mahwah, NJ: Erlbaum.
- Barab, S.A., & Hay, K.E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38, 70-102.
- Barnes, B., & Bloor, D. (1982). Relativism, rationalism and the sociology of knowledge. In M. Hollis, & S. Lukes (Eds.), *Rationality and relativism* (pp. 21-47). Cambridge, MA: The MIT Press.
- Bauchspies, W.K. (2005). Sharing shoes and counting years: Mathematics, colonialization, and communication. In A. Chronaki, & I.M. Christiansen (Eds.), *Challenging perspectives on mathematics classroom communication* (pp. 237-259). Greenwich, CT: Information Age Publishing.
- Bauchspies, W.K., Croissant, J., & Restivo, S. (2006). *Science, technology, and society. A sociological approach*. Malden, MA: Blackwell Publishing.

- Beaulieu, A. (2010). From co-location to co-presence: Shifts in the use of ethnography for the study of knowledge. *Social Studies of Science*, 40(3), 453-470. doi: 10.1177/0306312709359219
- Bencze, L., & Hodson, D. (1998). Coping with uncertainty in elementary school science: A case study in collaborative action research. *Teachers and Teaching*, 4(1), 77-94.
- Berland, L.K. (2011). Explaining variation in how classroom communities adapt the practice of scientific argumentation. *Journal of the Learning Sciences*, 20, 625-664. doi: 10.1080/10508406.2011.59171
- Berland, L.K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching*, 49, 68-94. doi: 10.1002/tea.20446
- Berry, R.A. W. (2006). Inclusion, power, and community. Teachers and students interpret the language of community in an inclusion classroom. *American Educational Research Journal*, 43, 489-529.
- Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practices. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (pp.269-292). Mahwah, NJ: Erlbaum.
- Bloom, J. W. (2006). *Creating a classroom community of young scientists* (2nd ed.). New York, NY: Routledge.

- Bloor, D. (1991). The strong program in the sociology of knowledge. In D. Bloor (Ed.), *Knowledge and social imagery* (2nd ed., pp. 2-23). Chicago, IL: The University of Chicago Press.
- Boon, M., & Knuuttila, T. (2009). Models as epistemic tools in engineering sciences. In A. Meijers (Ed.), *Handbook of the philosophy of science: Philosophy of technology and engineering sciences* (pp. 693-724). Burlington, MA: North Holland.
- Boylan, M. (2010). Ecologies of participation in school classrooms. *Teaching and Teacher Education*, 26(1), 61-70.
- Bransford, J.D., Brown, A.L., & Cocking, R.R. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: The National Academies Press.
- Bricker, L.A., & Bell, P. (2008). Conceptualizations of argumentation from science studies and the learning sciences and their implications for the practices of science education. *Science Education*, 92, 473-498. doi: 10.1002/sce.20278
- Britten, N., Campbell, R., Pope, C., Donovan, J., Morgan, M., & Pill, R. (2002). Using meta-ethnography to synthesise qualitative research: A worked sample. *Journal of Health Services Research & Policy*, 7(4), 209-215.
- Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Bucciarelli, L.L. (1994). *Designing engineers*. Cambridge, MA: The MIT Press.

- Burns, A., & Knox, J.S. (2011). Classroom as complex adaptive systems: A relational model. *The Electronic Journal for English as a Second Language*, 15(1).
Retrieved from <http://www.tesl-ej.org/wordpress/issues/volume15/ej57/ej57a1/>
- Buxton, C.A. (2001). Modeling science teaching on science practice? Painting a more accurate picture through an ethnographic lab study. *Journal of Research in Science Teaching*, 38, 387-407.
- Bybee, R. (2010). *The teaching of science: 21st-century perspectives*. Arlington, VA: NSTA Press.
- Carlone, H.B. (2004). The cultural production of science in reform based physics: Girls' access, participation and resistance. *Journal of Research in Science Teaching*, 41, 392-414.
- Carlone, H.B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, 44, 1187-1218. doi: 10.1002/tea.20006.
- Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic reasoning in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86, 175-218.
- Choi, M. (2006). Communities of Practice: An alternative learning model for knowledge creation. *British Journal of Educational Technology*, 37(1), 143-146.

- Christiansen, C. (2010). Creating classroom communities of practice: Students as practitioners of content. Retrieved from http://archives.evergreen.edu/masterstheses/Accession89-10MIT/Christiansen_MIT2010.pdf
- Clark, P. G. (2005). *The emergence of a classroom community of practice in a mathematical structures course*. (Doctoral Dissertation). Retrieved from ProQuest Dissertations and Theses. (3178229)
- Cobb, P., Stephan, M., McClain, K., & Gravemeijer, K. (2001). Participating in classroom mathematical practices. *Journal of the Learning Science*, 10, 113-163.
- Cole, S., & Cole, J. (1973). *Social stratification in science*. Chicago, IL: The University of Chicago Press.
- Collins, A. (2006). Cognitive Apprenticeship. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 47-77). New York, NY: Cambridge University Press.
- Cornelius, L. L., & Herrenkohl, L.P. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. *Cognition and Instruction*, 22, 467-498.
- Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage.

- Crnkovic, G.D. (2010). Constructive research and info-computational knowledge generation. In L. Magnani, W. Carnielli, & C. Pizzi (Eds.), *Model based reasoning in science and technology: Abduction, logic and computational discovery* (pp. 359-380). Heidelberg, Germany: Springer.
- den Brok, P., van Tartwijk, J., Wubbels, Th., & Veldman, I. (2010). The differential effect of the teacher-student interpersonal relationship on student outcomes for students with different ethnic backgrounds. *British Journal of Educational Psychology*, 80, 199-221. doi: 10.1348/000709909X465632
- DePalma, R., & Teague, L. (2008). A democratic community of practice: Unpicking all those word. *Educational Action Research*, 16(4), 441-456. doi: 10.1080/0965079080244561
- Doyle, L.H. (1998, April). A framework for examining school leadership and teaching in varied organizations and social contexts: A synthesis. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.
- Doyle, L.H. (2003). Synthesis through meta-ethnography: Paradoxes, enhancements and possibilities. *Qualitative Research*, 3(3), 321-344.
- Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5-12.
- Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic and social learning goals. *Review of Research in Education*, 32(1), 268-291.

- Eckert, P., & Wenger, E. (1994). From school to work: An Apprenticeship in institutional identity. *Working Papers on Learning and Identity*, 1. Palo Alto: Institute for Research on Learning. Retrieved from <http://www.stanford.edu/~eckert/PDF/transition.pdf>
- Edelson, D. (1998). Realising authentic science learning through the adaptation of scientific practice. In B.J. Fraser, & K.G. Tobin (Eds.), *International handbook of science education* (pp. 317-331). Dordrecht, the Netherlands: Kluwer.
- Elbers, E., & Streefland, L. (2000). Collaborative learning and the construction of common knowledge. *European Journal of Psychology of Education*, 15(4), 479-490.
- Engle, R.A., & Conant, F.R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, 20, 399-484.
- Enyedy, N., & Goldberg, J. (2004). Inquiry in interaction: How local adaptations of curricula shape classroom communities. *Journal of Research in Science Teaching*, 41, 505-535. doi:10.1002/tea.20031.
- Erickson, M. (2005). *Science, culture, and society: Understanding science in the 21st century*. Malden, MA: Polity Press.
- Evertson, C., Poole, I., & the IRIS Center. (2003). Norms and expectations. Retrieved from http://iris.peabody.vanderbilt.edu/case_studies/ICS-003.pdf

- Faubion, J.D., & Marcus, G.E. (2009). *Fieldwork is not what it used to be: Learning anthropology's method in a time of transition*. Ithaca, NY: Cornell University Press.
- Feldman, A., Divoll, K., & Rogan-Klyve, A. (2009). Research education of new scientists: Implications for science teacher education. *Journal of Research in Science Teaching*, 46, 442-459. doi: 10.1002/tea.20285.
- Ferrari, J.R., McCarthy, B.J., & Milner, L.A. (2009). Involved and focused? Students' perceptions of institutional identity, personal goal orientation and levels of campus engagement. *College Student Journal*, 43(3), 886-896.
- Fogelberg, H., & Glimell, H. (2003). *Bringing visibility to the invisible: Towards a social understanding of nanotechnology*. Göteborg, Sweden: Göteborg University Press.
- Ford, M. (2008). Disciplinary authority and accountability in scientific practice and learning. *Science Education*, 92, 404-423.
- Franke, A., & Dahlgren, L. O. (1996). Conceptions of mentoring: An empirical study of conceptions of mentoring during the school-based teacher education. *Teaching and Teacher Education*, 12(6), 627-641.
- Freeman, T.M., Anderman, L.H., & Jensen, J.M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *Journal of Experimental Education* 75(3), 203-220.
- Freire, P. (2000). *Pedagogy of the oppressed* (30th Ed.). New York, NY. Continuum Books.

- Gallego, M. A., Cole, M., & The Laboratory of Human Cognition. (2001). Classroom cultures and cultures in the classroom. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 951-997). Washington, DC: American Educational Research Association.
- Gitlin, A., Buendia, E., Crosland, K., & Doumbia, F. (2003). The production of margin and center: Welcoming-unwelcoming of immigrant students. *American Educational Research Journal*, 40, 91-122.
- Glaser, B. G., & Strauss, A. M. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine.
- Good, T. L., & Brophy, J. E. (2000). *Looking in classrooms* (8th ed.). New York, NY: Longman.
- Goos, M., Galbraith, P., & Renshaw, P. (1999). Establishing a community of practice in a secondary mathematics classroom. In L. Burton (Ed.), *Learning mathematics: From hierarchies to networks* (pp. 36-61). London, UK: Falmer Press.
- Greeno, J. G. (2002). Students with competence, authority and accountability: Affording intellectual identities in classrooms. New York, NY: College Board
- Greeno, J.G. (2006). Learning in activity. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 79-96). New York, NY: Cambridge University Press.
- Graue, M.E., & Walsh, D.J. (1998). *Studying children in context: Theories, methods and ethics*. Thousand Oaks, CA: Sage.

- Guberman, J., Saks, J., Shapiro, B., & Torchia, M. (2006). Mentoring and being mentored. In J. Guberman, J. Saks, B. Shapiro, & M. Torchia (Eds.), *Making the right moves: A practical guide to scientific management for postdocs and new faculty* (2nd ed., pp. 97-112). Research Triangle Park, NC & Chevy Chase, MD: Burroughs Wellcome Fund and the Howard Hughes Medical Institute.
- Gutierrez, K., & Rogoff, B. (2003). Cultural ways of learning: Individual traits of cultural repertoires of practice. *Educational Researcher*, 32(5), 19-25.
- Hackett, E. J., Amsterdamska, O., Lynch, M., & Wajcman, J. (2007). *The handbook of science and technology studies* (3rd ed.). Cambridge, MA: The MIT Press.
- Hammersley, M., & Atkinson, P. (2007). *Ethnography: Principles in practice*. London, UK: Routledge.
- Hayes, M. T. (2002). Elementary preservice teachers' struggles to define inquiry-based science teaching. *Journal of Science Teacher Education*, 13(2), 147-165.
- Herrenkohl, L. R. & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction*, 16, 431-473. doi: 10.1207/s1532690xcil604_3.
- Herrenkohl, L. R., Palincsar, A. S., DeWater L. S., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A sociocognitive approach. *Journal of the Learning Sciences*, 8, 451-493.
- Hofstein, A., & Lunetta, V.N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88, 28-54.

- Hogan, K., & Corey, C. (2001). Viewing classrooms as cultural contexts for fostering scientific literacy. *Anthropology and Education Quarterly*, 32(2), 214-243.
- Höngström, P., Ottander, C., & Benckert, S. (2010). Lab work and learning in secondary school chemistry: The importance of teacher and student interaction. *Research in Science Education*, 40(4), 505-523. doi: 10.1007/s11165-009-9131-3.
- Hoyningen-Huene, P. (2006). Context of discovery versus context of justification and Thomas Kuhn. In J. Schickore, & F. Steinle (Eds.), *Revisiting discovery and justification: Historical and philosophical perspectives on the context distinction* (pp. 119-131). Dordrecht, the Netherlands: Springer.
- Jocuns, A. (2009). Participation structures as a mediational means: Learning Balinese Gamelan in the United States through intent participation, mediated discourse, and distributed cognition. *Mind, Culture, and Activity*, 16(1), 48-63. doi: 10.1080/1074903080247734
- Johnson, W. B. (2003). A framework for conceptualizing competence to mentor. *Ethics and Behavior*, 13 (2), 127-151.
- Kantorovich, A. (1988). Philosophy of science: From justification to explanation. *The British Journal for the Philosophy of Science*, 39(4), 469-494.
- Kelly, G.J., Carlsen, W.S., & Cunningham, C.M. (1993). Science education in sociocultural context: Perspectives from the sociology of science. *Science Education*, 77, 207-220.

- Kirch, S.A. (2010). Identifying and resolving uncertainty as a mediated action in science: A comparative analysis of the cultural tools used by scientists and elementary science students at work. *Science Education*, 94, 308-335.
- Knorr-Cetina, K. (1981). *The manufacture of knowledge: An essay on the constructivist and contextual nature of science*. Oxford, UK: Pergamon.
- Knorr-Cetina, K. D. (1983). The ethnographic study of scientific work: Toward a constructivist interpretation of science. In K. Knorr-Cetina, & M. Mulkay (Eds.), *Science observed: Perspectives on the social study of science* (pp. 115-140). Beverly Hills, CA: Sage.
- Knorr-Cetina, K. (1995). Laboratory studies: The cultural approach to the study of science. In S. Jasanoff, G. E. Markle, J. C. Peterson, & T. J. Pinch (Eds.), *Handbook of science and technology studies* (pp. 140-166). Thousand Oaks, CA: Sage.
- Knorr-Cetina, K. (1999). *Epistemic cultures: The cultures of knowledge societies*. Cambridge, MA: Harvard University Press.
- Knorr Cetina, K. (2001). Laboratory studies: Historical perspectives. *International Encyclopedia of the Social & Behavioral Sciences* (pp. 8232-8238). Amsterdam, the Netherlands: Elsevier. doi:10.1016/B0-08-043076-7/03175-2
- Koballa, T. R., & Bradbury, L. (2009). Mentoring in support of science teaching. In A. Collins, & N. Gillespie (Eds.), *The continuum of secondary science teacher preparation: Knowledge, questions, and research recommendations* (pp. 171-185). Boston, MA: Sense Publishers.

- Kovalainen, M., & Kumpulainen, K. (2007). The social construction of participation in an elementary classroom community. *International Journal of Educational Research*, 46, 141-158. doi:10.1016/j.ijer.2007.09.011
- Kozulin, A., Gindis, B., Ageyev, V.S., & Miller, S.M. (2003). Sociocultural theory and education: Students, teachers, and knowledge. In A. Kozulin, B.A. Gindis, V.S. Ageyev, & S.M. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 1-14). Cambridge, MA: Cambridge University Press.
- Kuhn, T. (1962). *The structure of scientific revolutions* (1st ed.). Chicago, IL: The University of Chicago Press.
- Kuhn, T. (1996). *The structure of scientific revolutions* (3rd ed.). Chicago, IL: The University of Chicago Press.
- Kumpulainen, K., & Renshaw, P. (2007). Cultures of learning. *International Journal of Educational Research*, 46, 109-115.
- Langley, P., & Shrager, J. (2002). Computational discovery of communicable scientific knowledge. In L. Magnani, N.J. Nersessian, & C. Pizzi (Eds.), *Logical and computational aspects of model-based reasoning* (pp. 201-225). Dordrecht, the Netherlands: Kluwer.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, MA: Cambridge University Press.
- Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Milton Keynes, UK: Open University Press.

- Latour, B. (1999). *Pandora's hope: Essays on the reality of science studies*. Cambridge, MA: Harvard University Press.
- Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press.
- Lazaro, M., & Marcos, E. (2005). Research in software engineering: Paradigms and methods. In J. Castro, & E. Teniente (Eds.), *Proceedings of the CAiSE 05 Workshops* (Vol. 2, pp. 517-522). Porto, Portugal: FEUP.
- LeCompte, M.L. (2000). Analyzing qualitative data. *Theory into practice*, 39(3), 146-154.
- LeCompte, M.D., & Schensul, J.J. (1999). *Analyzing and interpreting ethnographic data*. Walnut Creek, CA: Altamira Press.
- LeCompte, M.D., & Schensul, J.J. (Eds.) (2010). *Designing and conducting ethnographic research: An introduction* (2nd ed.). Walnut Creek, CA: Altamira Press.
- Lemke, J.J. (1990). *Talking science: Language, learning and values*. Norwood, NJ: Ablex.
- Lensmire, T. (2000). *Powerful writing, responsible teaching*. New York, NY: Teachers College Press.
- Logan, R.K., & Schumann, J. H. (2005). The symbolosphere, conceptualization, language, and neo-dualism. *Semiotica*, 155(1-4), 201-214.

- Loh, B., Marshall, S. K., Radinsky, J., Mundt, J., & Alamar, K. (1999, April). Helping students build inquiry skills by establishing classroom norms: How teachers appropriate software affordances. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Quebec, Canada.
- Louca, L.T., Zacharia, Z.C., & Constantinou, C.P. (2011). In quest of productive modeling based learning discourse in elementary school science. *Journal of Research in Science Teaching*, 48, 919-951. doi: 10.1002/tea.20435
- Louvel, S. (2005). La construction locale des laboratoires. Approche ethnographique de dynamiques d'évolution de laboratoires académiques en France. PhD thesis in sociology, Université P. Mendès- France, Grenoble. Dissertation Abstracts. Retrieved from http://science.societe.free.fr/documents/pdf/these_Severine_Louvel.pdf
- Lynch, M. (1985). *Art and artifact in laboratory science: A study of shop work and shop talk in a research laboratory*. Boston, MA: Routledge & Kegan Paul.
- Marcus, G.E., & Fischer, M.M.J. (1999). *Anthropology as cultural critique: An experimental moment in the human sciences* (2nd ed.). Chicago, IL: The University of Chicago Press.
- McLaughlin, M. W., & Talbert, J.E. (2006). Developing communities of practice in schools. In M. W. McLaughlin, & J.E. Talbert (Eds.), *Building school-based teacher learning communities: Professional strategies to improve student achievement* (pp. 38-63). New York, NY: Teachers College Press.

- Melville, W., & Bartley, A. (2010). Mentoring and community: Inquiry as stance and science as inquiry. *International Journal of Science Education*, 32(6), 808-828. doi: 10.1080/09500690902914641
- Merton, R.K. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago, IL: The University of Chicago Press.
- Miller, J.H., & Page, S.E. (2007). *Complex adaptive systems: An introduction to computational models of social life*. Princeton, NJ: Princeton University Press.
- Moje, E. B. (1995). Talking about science: An interpretation of the effects of teacher talk in a high school science classroom. *Journal of Research in Science Teaching*, 32, 349-371.
- Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Maidenhead, UK: Open University Press.
- Munby, H., Cunningham, M., & Lock, C. (2000). School science culture: A case study of barriers to developing professional knowledge. *Science Education*, 84, 193-211.
- Nasir, N., & Cooks, J. (2009). Becoming a Hurdler: How learning settings afford identities. *Anthropology & Education Quarterly*, 40(1), 41-61. doi: 10.1111/j.1548-1492.2009.01027.x
- Nassaji, H., & Wells, G. (2000). What's the use of triadic dialogue? An investigation of student-teacher interaction. *Applied Linguistics*, 27(3), 376-406.

- National Research Council (2003). *Beyond the molecular frontier: Challenges for chemistry and chemical engineering*. Washington, DC: The National Academies Press.
- National Research Council (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: The National Academies Press.
- National Research Council (2010). *Exploring the intersection of science education and 21st century skills: A workshop summary*. Washington, DC: The National Academies Press.
- National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: The National Academies Press.
- Nersessian, N. J. (2005). Interpreting scientific and engineering practices: Integrating the cognitive, social, and cultural dimensions. In M. Gorman, R. Tweney, D. Gooding, & A. Kincannon (Eds.), *Scientific and technological thinking* (pp. 17-56). Mahwah, NJ: Erlbaum.
- Nersessian, N. J. (2006). The cognitive-cultural systems of the research laboratory. *Organization Studies*, 27, 125-145.
- Nersessian, N.J. (2009). How do engineering scientists think? Model-based simulation in biomedical engineering laboratories, *Topics in Cognitive Science*, 1, 730-757.

- Nersessian, N.J., & Patton, C. (2009). Model-based reasoning in interdisciplinary engineering. In A. Meijers (Ed.), *Handbook of the philosophy of science: Philosophy of technology and engineering sciences* (pp. 727-757). Burlington, MA: North Holland.
- Noblit, G.W., & Hare, R.D. (1988). *Meta-Ethnography: Synthesizing qualitative studies*. Beverly Hills, CA: Sage.
- Oliveira, A.W. (2010). Developing elementary teachers' understanding of the discourse structure of inquiry-based science classrooms. *International Journal of Science and Mathematics Education*, 8(2), 247-269.
- Oliveira, A.W. (2011). Science communication in teacher personal pronouns. *International Journal of Science Education*, 33(13), 1805-1833. doi: 10.1080/09500693.2010.510541
- Oliveira, A. W., & Sadler, T.D. (2008). Interactive patterns and conceptual convergence during student collaborations in science. *Journal of Research in Science Teaching*, 45, 634-658.
- Oliveira, A. W., Sadler, T. D., & Suslak, D. F. (2007a). The linguistic construction of expert identity in professor-student discussions of science. *Cultural Studies of Science Education*, 2(1), 119-150.
- Olitsky, S. (2007). Promoting student engagement in science: Interaction rituals and the pursuit of a community of practice. *Journal of Research in Science Teaching*, 44, 33-56. doi: 10.1002/tea.20128.

- Olitsky, S., Flohr, L.L., Gardner, J., & Billups, M. (2010). Coherence, contradiction, and the development of school science identities. *Journal of Research in Science Teaching*, 47, 1209-1228. doi: 10.1002/tea.20389.
- Osbeck, L.M., Nersessian, N.J., Malone, K.R., & Newstetter, W. C. (2011). *Science as psychology. Sense-making and identity in science practice*. New York, NY: Cambridge University Press.
- Osterman, K.F. (2000). Students' need for belonging in the school community. *Review of Educational Research* 70, 323-367.
- Owen-Smith, J. (2001). Managing laboratory work through skepticism: Processes of evaluation and control. *American Sociological Review*, 66(3), 427-452.
- Pace, J.L., & Hemmings, A. (2007). Understanding authority in classrooms: A review of theory, ideology, and research. *Review of Educational Research*, 77(1), 4-29. doi: 10.3102/003465430298489
- Paletz, S.B.F., & Schunn, C. (2010). A social-cognitive framework of multidisciplinary team innovation. *Topics in Cognitive Science*, 2, 73-95.
- Philips, S. (1972). Participant structures and communicative competence: Warm Springs children in community and classroom. In C. Cazden, V. P. John, & D. Hymes (Eds.), *Functions of language in the classroom* (pp. 370-394). New York, NY: Teachers College Press.
- Pickering, A. (1992). *Science as practice and culture*. Chicago: The University of Chicago Press.

- Pickering, A. (1995). *The mangle of practice: Time, agency, and science*. Chicago, IL: The University of Chicago Press.
- Pickering, A. (1999). The mangle of practice: Agency and emergence in the sociology of science. In M.Biagioli (Ed.), *The science studies reader* (pp. 373-393). New York, NY: Routledge.
- Polman, J. L. (2004). Dialogic activity structures for project-based learning environments. *Cognition and Instruction*, 22, 431-466.
- Restivo, S., & Croissant, J. (2008). Social constructionism in science and technology studies. In J.A. Holstein, & J.F. Gubrium (Eds.), *Handbook of constructionist research* (pp. 213-229). New York, NY: The Guilford Press.
- Restivo, S., & Zenzen, M. (1982). The mysterious morphology of immiscible liquids: A study of scientific practice. *Social Science Information*, 21(3), 447-473.
- Richardson, L., & St. Pierre, E.A. (2005). Writing: A method of inquiry. In N. Denzin, & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp. 959-978). Thousand Oaks, CA: Sage.
- Roberts, J. (2006). Limits to communities of practice. *Journal of Management Studies*, 43(3), 623-639.
- Roth, M-W. (1995). *Authentic school science: Knowing and learning in open-inquiry science laboratories*. Dordrecht, the Netherlands: Kluwer.
- Roth, W-M. (1998). *Designing communities*. Dordrecht, the Netherlands: Kluwer.
- Roth, W-M. (2006). Learning from laboratory activities. In K. Tobin (Ed.), *Teaching and learning science: A handbook* (pp.51-60). Westport, CT: Praeger.

- Roth, W-M., McGinn, M. K., Woszczyna, C., & Boutonne, S. (1999). Differential participation during science conversations: The interaction of focal artifacts, social configurations, and physical arrangements. *Journal of the Learning Sciences*, 8, 293-347.
- Roychoudhury, A., & Roth, W-M. (1996). Interaction in open inquiry physics laboratory. *International Journal of Science Education*, 18(4), 423-445.
- Rudolph, J.L. (2003). Portraying epistemology: School science in historical context. *Science Education*, 87, 64-79.
- Sawyer, R.K. (2006). Introduction: The new science of learning. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 1-16). New York, NY: Cambridge University Press.
- Sergiovanni, T. (1994). *Building community in schools*. San Francisco, CA: Jossey-Bass.
- Shanahan, M.-C., & Nieswandt, M. (2011). Science student role: Evidence of social structural norms specific to school science. *Journal of Research in Science Teaching*, 48, 367-395. doi: 10.1002/tea.20406
- Shepardson, D.P., & Britsch, S.J. (2006). Zones of interaction: Differential access to elementary science discourse. *Journal of Research in Science Teaching*, 43, 443-466.
- Sismondo, S. (2010). *An introduction to science and technology studies* (2nd ed.). West Sussex, UK: John Wiley & Sons.

- Smetana, L.K., & Bell, R.L. (in press). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education*. doi:10.1080/09500693.2011.605182
- Smithenry, D. W., & Gallagher-Bolos, J. A. (2010, March). Connecting a student-directed participant structure to the acquisition of collaborative skills. Paper presented at the annual meeting of the National Association of Research in Science Teaching, Philadelphia, PA.
- Spradley, J.P. (1980). *Participant observation*. New York, NY: Holt, Rinehart, & Winston.
- Star, L.S., & Griesemer, J. R. (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science*, 19(3), 387-420.
- Strauss, A.L., Corbin, J. M. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage.
- Tabak, I., & Baumgartner, E. (2004). The teacher as partner: Exploring participant structures, symmetry, and identity work in scaffolding. *Cognition and Instruction*, 22, 393-429.
- Thiry, H., & Laursen, S.L. (2011). The role of student-advisor interactions in apprenticing undergraduate researchers into a scientific community of practice. *Journal of Science Education and Technology*, 20(6), 771-784. doi: 10.1007/s10956-010-9271-2

- Thompson, B.M., & Parrott, J.L. (2003, April). Investigating the impact of the authentic science experiences in the Information Technology in Science (ITS) Center for teaching and learning on teachers' beliefs. Paper presented at the annual meeting of the American Education Research Association, Chicago, IL.
- Thorne, S., Jensen, L., Kearney, M.H., Noblit, G., & Sandelowski, M. (2004). Qualitative metasynthesis: Reflections on methodological orientation and ideological agenda. *Qualitative Health Research*, 14(10), 1342-1365.
- Tobin, K. G. (2012). Sociocultural perspectives on science education. In B.J. Fraser, K.G. Tobin, & C.J. McRobbie (Eds.), *Second international handbook of science education* (pp.3-18). New York, NY: Springer.
- Traweek, S. (1988). *Beamtimes and lifetimes: The world of high energy physicists*. Cambridge, MA: Harvard University Press.
- Turner, S., & Sullenger, K. (1999). Kuhn in the classroom, Lakatos in the lab: Science educators confront the nature-of-science debate. *Science, Technology & Human Values*, 24(1), 5-30.
- Turpen, C., & Finkelstein, N.D. (2010). The construction of different classroom norms during peer instruction: Students perceive differences. *Physical Review Special Topics- Physics Education Research*, 6(2), 1-22. doi: 10.1103/PhysRevSTPER.6.020123
- Vinck, D. (2003). *Everyday engineering: An ethnography of design and innovation*. Cambridge, MA: The MIT Press.

- Vinck, D. (2007). Back to the laboratory as a knowledge production space. *Revue d'anthropologie des connaissances*, 2(2), 159-165.
- Vinck, D. (2010). *The sociology of scientific work: The fundamental relationship between science and society*. Northampton, MA: Edward Elgar.
- Wang, J., & Odell, S. J. (2007). An alternative conception of mentor-novice relationships: Learning to teach in reform-minded ways as a context. *Teaching and Teacher Education*, 23(4), 473-489.
- Watson, M., & Battistich, V. (2006). Building and sustaining caring communities. In C. M. Evertson, & C. S. Weinstein (Eds.), *Handbook of classroom management: Research, practice, and contemporary issues* (pp. 253-279). Mahwah, NJ: Erlbaum.
- Weinstein, M. (2008). Finding science in the school body: Reflections on transgressing the boundaries of science education and the social studies of science. *Science Education*, 92, 389-403.
- Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. New York, NY: Cambridge University Press.
- Wenger, E. (2010). Communities of practice and social learning systems: The career of a concept. In C. Blackmore (Ed.), *Social learning systems and communities of practice* (pp.179-198). London, UK: Open University. doi: 10.1007/978-1-84996-133-2_11
- Wenger, E., McDermott, R., & Snyder, W.M. (2002). *Cultivating communities of practice*. Boston, MA: Harvard Business School Press.

- Wertsch, J. V. (1998). *Mind as action*. New York, NY: Oxford University Press.
- Yerrick, R., & Roth, W. -M. (Eds.). (2005). *Establishing scientific classroom discourse communities: Multiple voices of research on teaching and learning*. Mahwah, NJ: Erlbaum.
- Ziman, J. (2000). *Real science: What it is and what it means*. New York, NY: Cambridge University Press.

APPENDIX A

INTERVIEW PROTOCOL IN ENGINEERING RESEARCH COMMUNITY

1. What is your role at the research center?
2. Briefly, can you talk about the activities you do at the research center?
3. What kind of investigations do you conduct at the research center?
4. What are the scientific investigations that take place in laboratory?
5. How do you generate models? How is this process implemented?
6. For what purposes do you generate and use models?
7. How do you share your findings/results with your colleagues?
8. Can you talk about the working environment (individual or collaborative) at research center?
9. Can you talk about social interactions/communications with research center members (colleagues or scientists, post-doc or PhD. students)? How these interactions help you conduct your research?
10. What do you think the role of collaboration in creating your protein models?
11. How do you explain the role of research center within the context of knowledge/model generation?
12. In your opinion, what is science?
13. How is scientific knowledge generated/produced/constructed?

APPENDIX B

INTERVIEW PROTOCOLS IN SCHOOL SCIENCE COMMUNITY

1. What is the purpose/goal/activity and common practice of your classroom community?
2. Who determines activities taking place in your classroom or laboratory? How, do you think, is it being determined? How is it expressed/or communicated?
3. What makes you participate in these class or lab activities/discussions?
4. What is your role during the class or lab activities/discussions?
5. How is your role being determined?
6. In what types of roles do you like to be engaged?
7. Do you see your class as a community? How?
8. How can you explain your class community membership? (Or how can you explain your role as a member in your class community?)
9. What artifacts/symbols/tools/words/concepts are used to give meaning to this community? (Or what are the common language/words/sayings/artifacts do you have? And how do they make sense in your communication with others in class?)

VITA

Name: Mehmet Cihad Ayar

Address: 346 Harrington Tower, MS 4232, College Station, TX, 77843-4232

Email Address: mehmetayar@tamu.edu

Education: Integrated BS and MS Program in Chemistry Education (M.S in Secondary School Science and Mathematics Education), Bogazici University, Istanbul, Turkey, 2003
M.S., Science Education, Marmara University, Istanbul, Turkey, 2007
Ph.D., Curriculum & Instruction, Texas A&M University, Texas, 2012